SCHOOL OF CIVIL ENGINEERING

INDIANA DEPARTMENT OF HIGHWAYS

Implementation Report (1)

FHWA/IN/JHRP-86/17

FINITE ELEMENT ANALYSIS OF PLANE STRAIN PROBLEMS WITH PS-NSFAP AND THE CAP MODEL -- USER'S MANUAL

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PURDUE UNIVERSITY

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FINITE ELEMENT ANALYSIS
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PLANE STRAIN PROBLEMS
with
PS-NFAP AND THE CAP MODEL
- USER'S MANUAL -

by

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Joint Highway Research Project

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Conducted by

Joint Highway Research Project
Engineering Experiment Station
Purdue University

in cooperation with the

Indiana Department of Highways

Purdue University
West Lafayette, Indiana
October 14, 1986

Implementation Report (1)

FINITE ELEMENT ANALYSIS OF PLANE STRAIN
PROBLEMS WITH PS-NFAP AND THE CAP MODEL
-- USER'S MANUAL --

TO:	H. L. Michael, Director Joint Highway Research Project	DATE:	October 14, 1986
		PROJECT:	C-36-36Q
FROM:	R. D. Holtz, Research Engineer Joint Highway Research Project	FILE:	6-14-17

Attached is a user's manual on the HPR Part II research study entitled "Design of Reinforced Embankments." This report is the implementation part of Task 4 of the approved work plan. The authors of the report are D. N. Humphrey, W. O. McCarron, W. F. chen, and myself.

The user's manual describes the operation of the finite element program PS-NFAP developed in this research. The program analyzes plane strain problems such as highway embankments on soft foundations using a cap type soil plasticity behavior model. The use of four other programs necessary for the complete analysis is also described. Nos. (1) and (2), CPCALC and CAP, calculate the required cap model parameters from the results of typical soils tests. No. (3) AUTOGEN generates the input file for PS-NFAP, and No. (4) NFMINX optimizes the node numbering of the finite element mesh used in the problem. PS-NFAP has a number of features specially adapted for the design of reinforced and unreinforced embankments on soft foundations. A detailed example illustrating how the series of programs are used is also given in the manual. The report is essential to highway engineers contemplating using PS-NFAP for the analysis of embankments on soft foundations.

Copies of the report will be submitted to the IDOH and FHWA for their review. My co-authors and I look forward to receiving their comments on the manual.

Sincerely yours,

R. D. Holtz, Ph.D., P.E.
Research Engineer

RDH/kr
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16. Abstract

This user's manual describes the operation of PS-NFAP, a finite element program developed for the analysis of plane strain problems with the cap soil behavioral model. In addition, two programs (CPCALC and CAP) that assist in calculating the cap model parameters from typical soil tests results, a preprocessor program (AUTOGEN) that generates the PS-NFAP input file, and an auxiliary program (NFMINX) that optimizes the FE mesh node numbering are described. PS-NFAP has special features for analysis of reinforced and unreinforced embankments constructed on soft ground. A detailed example to illustrate how the series of programs are used to analyze a reinforced embankment is given.

The programs are written in FORTRAN IV and FORTRAN77. They are implemented on two computer systems: (1) IBM 3083 mainframe using VS-FORTRAN; and (2) the series of IBM personal computers with a math co-processor chip using Ryan-McFarland FORTRAN, version 2.0 (Ryan-McFarland, 1985). The IBM personal computers include the IBM-PC, IBM-XT, IBM-AT, or compatible computers.

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FE ANALYSIS OF PLANE STRAIN PROBLEMS WITH PS-NFAP AND THE CAP SOIL MODEL

USER'S MANUAL

INTRODUCTION

This user's manual describes operation of PS-NFAP, a finite element program for analysis of plane strain problems with the cap soil behavior model. In addition, two programs (CPCALC and CAP) that assist in calculating the cap model parameters from typical soil tests results, a preprocessor program (AUTOGEN) that generates the PS-NFAP input file, and an auxiliary program (NFMINX) that optimizes the FE mesh node numbering are described. PS-NFAP has special features for analysis of reinforced and unreinforced embankments constructed on soft ground (McCarron, 1985; Humphrey and Holtz, 1986). A detailed example that illustrates how the series of programs are used to analyze a reinforced embankment is given. Details of the cap model are given in McCarron (1985) and Humphrey and Holtz (1986). Procedures to determine the cap parameters from soil test results are given in Humphrey and Holtz (1986). Only aspects of the model that deal specifically with program operation are discussed herein. All the programs use the convention that compressive stresses and strains are negative. In several instances the stresses are expressed in terms of the first invariant I_1' and the second invariant of the stress deviator tensor J_2 where

$$I_1' = \sigma_1' + \sigma_2' + \sigma_3'$$

$$J_2 = (\sigma_1-\sigma_2)^2 + (\sigma_2-\sigma_3)^2 + (\sigma_3-\sigma_1)^2$$

and where: σ_1 = major principal stress

σ_2 = intermediate principal stress

σ_3 = minor principal stress

The programs are written in FORTRAN IV and FORTRAN77. They are implemented on two computer systems: (1) IBM 3083 mainframe using VS-FORTRAN; and (2) the series of IBM personal computers with a math co-processor chip using Ryan-McFarland FORTRAN, version 2.0 (Ryan-McFarland, 1985). The IBM personal computers include the IBM-PC, IBM-XT, IBM-AT, or compatible computers and are collectively referred to as IBM-PC computers in this manual.

An overview of the steps in the analysis procedure is given in the next section. A description of each program and input instructions are given in the Appendices. CPCALC and CAP are described in Appendices A and B, respectively. AUTOGEN is described in Appendix C. PS-NFAP and NFMINX are described in Appendix D. Appendix E shows how the programs are used to analyze reinforced embankments constructed on soft ground; also, example input and output files for each program are given.

OVERVIEW OF ANALYSIS PROCEDURE

The first step in the analysis procedure is to calculate the cap parameters from soil test results using the procedures given in Humphrey and Holtz (1986). Three of the critical parameters are calculated using CPCALC as described in Appendix A. In addition, there are several cap parameters which control execution of CAP and PS-NFAP. These are described in Appendices B and D.

The next step is to compare calculated response to behavior exhibited by representative laboratory test samples. For example, the calculated and observed stress strain curves from a triaxial test could be compared. This is done using the CAP program described in Appendix B. If necessary, the cap parameters can be adjusted to obtain a better fit using recommendations given in Humphrey and Holtz (1986).

Next the problem geometry is defined and the finite element mesh is selected using the example in Appendix E for guidance. Then the input file for PS-NFAP is prepared using the instructions in Appendix D. The preprocessor program AUTOGEN is used to generate much of the node, element, and load data as described in Appendix C. If the analysis will be carried out on an IBM-PC the auxiliary node renumbering program NFMINX is run. The nodes are renumbered by PS-NFAP in the mainframe version.

The final step is to run the analysis using PS-NFAP. The input file should be carefully checked for errors. The program output should be examined to be sure the calculated results are reasonable. The steps in the analysis procedure are summarized in Fig. 1 and illustrated with the example in Appendix E.

REFERENCES

1. Humphrey, D. N., and Holtz, R. D. (1986), "Design of reinforced embankment," Joint Highway Research Project Report, School of Civil Engineering, Purdue University, West Lafayette, IN 47907.

2. McCarron, W. O. (1985), Soil Plasticity and Finite Element Applications, PhD. Thesis, School of Civil Engineering, Purdue University, West Lafayette, IN 47907.

3. Ryan-McFarland (1985), RM/FORTRAN User's Guide, Version 2, Ryan-McFarland Corporation, Rolling Hills Estates, CA 90274.

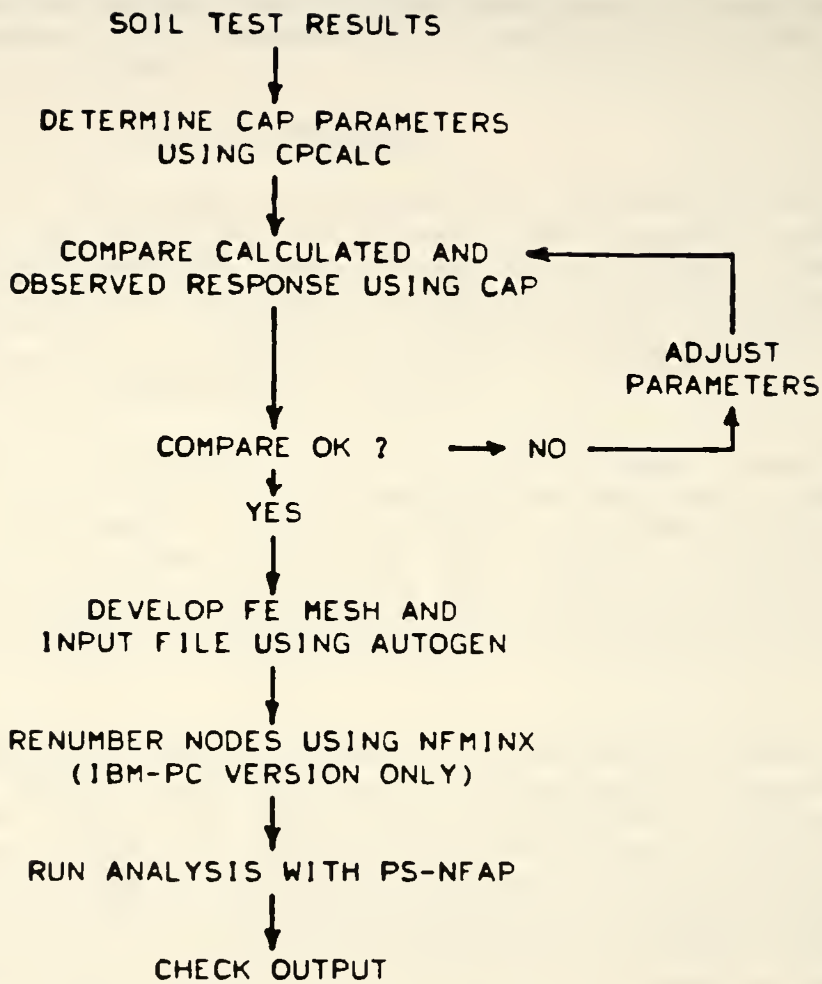


Fig. 1. Steps in analysis procedure.

APPENDIX A

CPCALC
PROGRAM TO CALCULATE CAP PARAMETERS

CPCALC is a program to compute three critical cap parameters, namely: the hardening parameters, Dx_o and $W/(a-b)$, and the aspect ratio, R. The program prompts the user for the soil properties shown in Table A.1.

The program uses the solution procedure given in Humphrey and Holtz (1986). The values of x_f/x_o, R_{max}, and $(x_f/x_o)_{max}$ are also computed. The calculated parameters are defined and their correspondence with the variable names used by CPCALC is shown in Table A.2. Example input and output is shown in Appendix E.

REFERENCE

1. Humphrey, D. N., and Holtz, R. D. (1986), "Design of reinforced embankments," Joint Highway Research Project Report, School of Civil Engineering, Purdue University, West Lafayette, IN 47907.

Table A.1
Input soil properties for program CPCALC

Soil property	Variable name	Description
α	am	slope of Drucker-Prager surface
κ/σ'_{vo}	acn	normalized $J_2^{1/2}$ intercept of Drucker-Prager surface
$J_{2f}^{1/2}/\sigma'_{vo}$	sJ2fn	normalized shear strength ratio
K_o	rkc	coefficient of lateral earth pressure at rest
$(a-b)/b$	abb	soil compressibility where a and b are slopes of virgin compression and unloading-reloading curves on ε_v-$\ln(\sigma'_v)$ plot from hydrostatic consolidation test

Note: The ratios acn and sJ2fn are negative since compressive stresses are negative

Table A.2
Cap parameters calculated by program CPCALC

Cap parameter	Variable name	Description
Dx_o	dxo	dimensionless hardening parameter
$W/(a-b)$	wab	normalized hardening parameter
R	r	cap aspect ratio
x_f/x_o	xfxo	ratio of failure to initial I_1 intercept of cap
R_{max}	rmax	maximum possible R for given input soil properties
$(x_f/x_o)_{max}$	xfxomx	maximum possible x_f/x_o for given input soil properties

APPENDIX B

CAP
PROGRAM TO CALCULATE SOIL RESPONSE

The CAP computer program uses the cap model shown in Fig. B.1 to calculate soil response due to a set of applied stresses or strains. Details of the cap model are given in McCarron (1985), Chen and Baladi (1985), and Humphrey and Holtz (1986). The CAP program was developed by McCarron and Chen (1986). Its main use is to compare calculated behavior to observed test sample behavior. For example, the stress-strain curve obtained from a triaxial compression test can be compared to the curve calculated by the program for a simulated sample with the same initial conditions subjected to the same stress path. If necessary, the cap parameters can be adjusted to obtain a better fit using the guidelines given in Humphrey and Holtz (1986). The program can model axisymmetric, plane strain, and plane stress conditions. Material nonlinearity or both material and geometric nonlinearity can be represented. The user specifies either the stress path and the program calculates the resulting strains and pore pressure or the strain path and the program calculates the resulting stresses and pore pressure. The results are output in tabular form. Stresses and pore pressure versus axial strain and stress path data are stored in two files for convenient input into commercial plotting programs.

The program is written in FORTRAN77 and consists of a main program, 15 subroutines, and a block data unit. It is implemented on an IBM-PC using Ryan-McFarland FORTRAN, Version 2.0 (Ryan-McFarland, 1985). Program execution is controlled by the main program. The purpose of the primary subroutines is summarized in Table B.1 and the purpose of the cap model subroutines is summarized in Table B.2. Although the cap model subroutines have the same names as in PS-NFAP there are slight differences between them and subroutines from CAP and PS-NFAP are not interchangeable. The program flowchart is shown in Fig. B.2. Input instructions are given in the first section of Appendix B.1 followed by comments to the input instructions. All input is free format. Recall that compressive stresses and strains are negative. To execute the program type:

```
C>CAP <FILE.IN >FILE.OUT
```

where FILE.IN is the name of the input file and FILE.OUT is the name of the output file. An example input file is shown in Appendix E.

The calculated strains become unbounded at failure. This causes error messages to be displayed on the screen or in the output file. When operated on a IBM-PC, the solution may be terminated at this point with the 'control-break' key or it may be allowed to continue until the iteration limit is exceeded.

The output file lists the control parameters, cap parameters, and calculated stress and strain components. In addition, two files are generated containing stress-strain behavior for use as input into commercial plotting programs. The first file is named 'plot.1' and contains ε_{zz}, $(\sigma_{zz}-\sigma_{yy})/(2\sigma'_{vo})$, $\Delta u/\sigma'_{vo}$, $\sigma'_{zz}/\sigma'_{yy}$ and $J_2^{1/2}/\sigma'_{vo}$ in columns 1 through 5, where:

ε_{zz} = axial or vertical strain

σ_{zz} = axial or vertical stress

σ_{yy} = radial or horizontal stress

Δu = excess pore water pressure

J_2 = second invariant of stress deviator tensor

σ'_{vo} = initial axial or vertical effective stress

The second file is named 'plot.2' and contains ε_{zz}, p', q, I'_1, and $J_2^{1/2}$ in columns 1 through 5, where:

$p' = (\sigma'_{zz}+\sigma'_{yy})/2$

$q = (\sigma_{zz}-\sigma_{yy})/2$

I'_1 = first invariant = $\sigma'_{xx} + \sigma'_{yy} + \sigma'_{zz}$

σ'_{xx} = lateral or horizontal stress

Note that ' indicates effective stress. Stresses and strains in the two plot files are output using the soil mechanics convention that compressive stresses and strains are positive. An example output is shown in Appendix E.1.

REFERENCES

1. Chen, W. F., and Baladi, G. Y. (1985), Soil Plasticity-Theory and Implementation, Elsevier Science Publishing Co., New York, 231 pp.

2. Humphrey, D. N., and Holtz, R. D. (1986), "Design of reinforced embankments," Joint Highway Research Project Report, School of Civil Engineering, Purdue University, West Lafayette, IN 47907.

3. McCarron, W. O. (1985), Soil Plasticity and Finite Element Applications, PhD. Thesis, School of Civil Engineering, Purdue University, West Lafayette, IN 47907, 266 pp.

4. McCarron, W. O., and Chen, W. F. (1986), "Documentation for a CAP model subroutine," Structural Engineering Report CE-STR-86-5, School of Civil Engineering, Purdue University, West Lafayette, IN 47907, 76 pp.

5. Ryan-McFarland (1985), RM/FORTRAN User's Guide, Version 2, Ryan-McFarland Corporation, Rolling Hills Estates, CA 90274.

Table B.1
Function of principal subroutines

Subroutine	Function
INIT	Initialize parameters and read and print material data
EL2D10	Access to cap model
RESET	Stores current material state on disk
MATSET	Sets coefficients in equilibrium equations and load vector
SOLVER	Forward/backward substitution of equilibrium equations
FUNCT2	Find interpolation functions and their derivatives
WRITES	Print stresses and strains to output; write material response to disk files 'plot.1' and 'plot.2' for input to plotting programs

Table B.2
Function of cap model subroutines

Subroutine	Function
EL2D10	Access to cap model
IEP210	Initialize material history
EP2D10	Driver for material model
EPL210	Compute material response for given strain increment
PRAGER	Form constitutive relation for Drucker-Prager material
MD2D10	Form constitutive relation for work hardening cap
MAXMIN	Determine principal stresses
DEVPRT	Determine stress invariants and deviatoric components
TENCT	Tensile loading

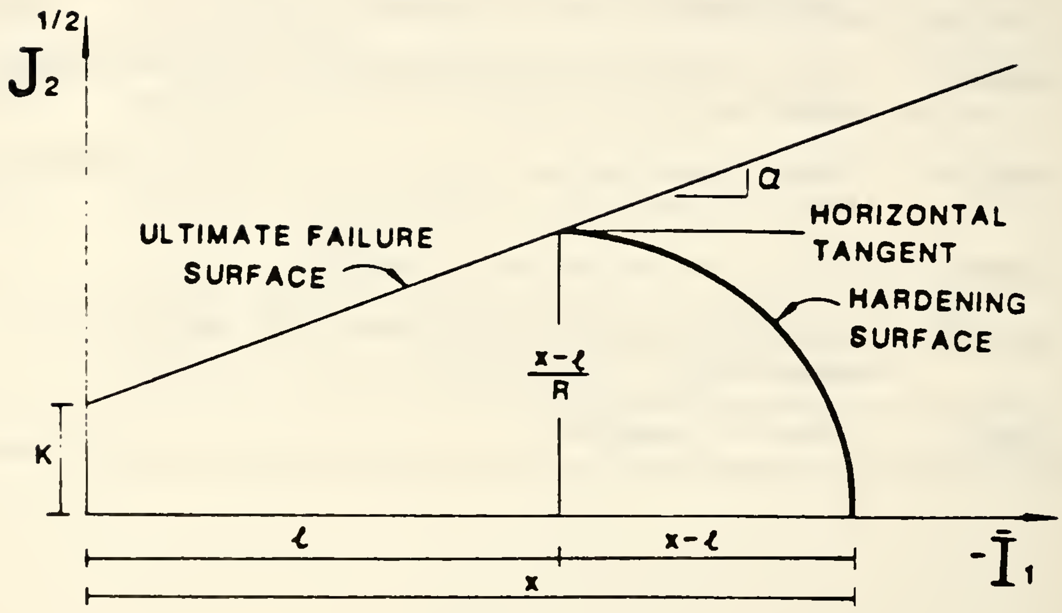


Figure B.1. Cap model.

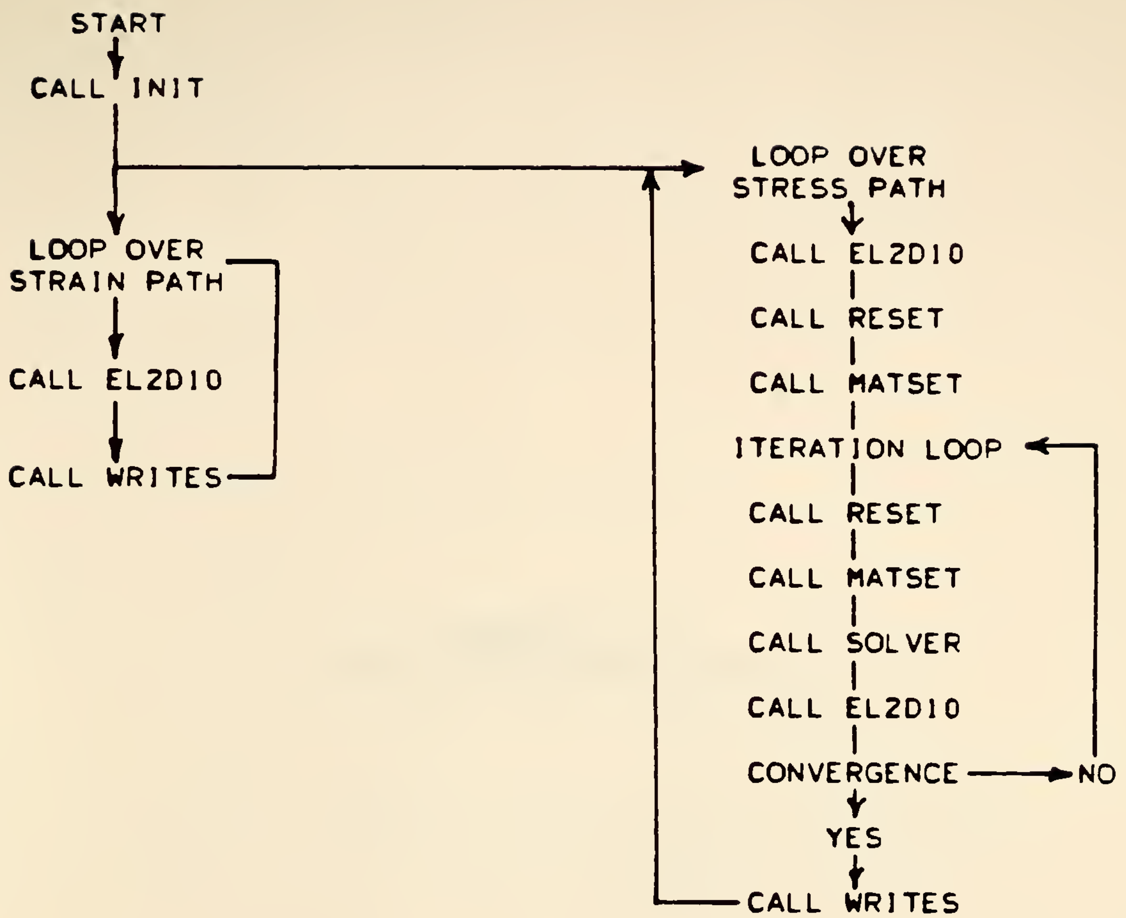


Figure B.2. Program flowchart.

APPENDIX B.1
INPUT INSTRUCTIONS FOR CAP

INPUT INSTRUCTIONS

>>> ALL INPUT IS FREE-FORMAT <<<

Card 1: HEADING

Variable	Comment*	Entry
TITLE	(1)	Enter the title for use in labeling the output

* Comments to the input instructions are given in the following section

Card 2: ANALYSIS INFORMATION

Variable	Comment	Entry
ITYP2D	(2)	Analysis type; .EQ. 0; axisymmetric case .EQ. 1; plane strain case .EQ. 2; plane stress case
INDNL	(3)	Type of nonlinear analysis; .EQ. 1; material nonlinearity only .EQ. 4; both material and geometric nonlinearity

Card 3: CAP PARAMETERS

Variable	Comment		Entry
PROP(1)	(4)	K_1	- bulk modulus parameter
PROP(2)	(4)	K_2	- bulk modulus parameter
PROP(3)	(4)	A_p	- atmospheric pressure
PROP(4)	(4)	K_{min}	- minimum bulk modulus
PROP(5)	(5)	G_1	- shear modulus parameter
PROP(6)	(5)	G_2	- shear modulus parameter
PROP(7)	(6)	AM	- slope of Drucker-Prager surface
PROP(8)	(6)	AC	- $J_2^{1/2}$ intercept of Drucker-Prager surface
PROP(9)	(7)	AW	- hardening parameter
PROP(10)	(7)	AD	- hardening parameter
PROP(11)	(8)	R	- cap aspect ratio
PROP(12)	(9)	XL	- I_1' coordinate of intersection of cap and Drucker-Prager surface .EQ. +1.; normally consolidated soil
PROP(13)	(10)	TENCUT	- limiting tensile strength
PROP(14)	(11)	STATE	- movement of cap .EQ. 1; expansion and contraction .GT. 1; expansion only
PROP(15)	(12)	A1	- unit weight of soil; must be 0.
PROP(16)	(13)	A2	- initial vertical stress
PROP(17)	(14)	K_o	- ratio of initial horizontal to vertical stress
PROP(18)	(16)	open	- not used; must be 0.
PROP(19)	(15)	FAC	- pore pressure response factor; .EQ. 0.; drained .GT. 0.; undrained .LT. 0.; undrained

Card 3: CAP PARAMETERS (CONTINUED)

Variable	Comment	Entry
PROP(20)	(16)	TIMEON - not used; must be 0.
PROP(21)	(16)	WGT - not used; must be 0.
PROP(22)	(16)	BOUY - not used; must be 0.

Card 4: SOLUTION TYPE

Variable	Comment	Entry
SOLTYP	(17)	Solution type .EQ. 'strain'; strain path specified .EQ. 'stress'; stress path specified

FOR STRAIN PATH SPECIFIED

Card 5: STRAIN PATH DATA

Variable	Comment	Entry
NTIMES	(18)	Number of times to apply strain increment
DSTRAIN(1)	(18)	$\Delta\varepsilon_{yy}$: radial or horizontal strain increment
DSTRAIN(2)	(18)	$\Delta\varepsilon_{zz}$: axial or vertical strain increment
DSTRAIN(3)	(18)	$\Delta 2\varepsilon_{yz}$: engineering shear strain increment
DSTRAIN(4)	(18)	$\Delta\varepsilon_{xx}$: radial or horizontal strain increment
DSTRAIN(5)	(19)	Δw; spin increment for large displacement analysis

Repeat card 5 for each set of strain increments. Input is terminated by a card 5 with NTIMES=0 and DSTRAIN(1)=0.; this must be the last card in the input file.

FOR STRESS PATH SPECIFIED

Card 5: ITERATION INFORMATION

Variable	Comment	Entry
RTOL	(20)	Solution tolerance for convergence; = ||unbalanced stress||/||total stress||
ITEMAX	(20)	maximum number of iterations allowed
IREF	(21)	maximum number of reformations of the constitutive relation

Card 6: STRESS PATH DATA

Variable	Comment	Entry
KSWTCH	(22)	Constitutive relation flag .EQ. 0; cap model constitutive relation .EQ. 1; elastic constitutive relation
NTIMES	(22)	Number of times to apply stress increment
DSIG(1)	(22)	$\Delta\sigma_{yy}$; radial or horizontal stress increment
DSIG(2)	(22)	$\Delta\sigma_{zz}$; axial or vertical stress increment
DSIG(3)	(22)	$\Delta\sigma_{yz}$; shear stress increment
DSIG(4)	(22)	$\Delta\sigma_{xx}$; radial or horizontal stress increment

Repeat card 6 for each set of stress increments. Input is terminated by a card 6 with NTIMES=0 and DSIG(I)=0.; this must be the last card in the input file.

COMMENTS FOR CAP INPUT INSTRUCTIONS

1. The TITLE is used to label the program output. It may be up to 80 characters long.

2. ITYP2D .EQ. 0 is used for triaxial test conditions. For this case the Z-axis is the axial direction and the Y-axis is the radial direction. ITYP2D .EQ. 1 is used for plane strain test conditions. For this case no strain is allowed in X-direction; the Z-axis is the vertical direction and the Y-axis is the horizontal direction. For ITYPE2D .EQ. 1, stress in the X-direction is constant.

3. INDNL should be the same as will be used in PS-NFAP. For most cases both material and geometric nonlinearity will be considered so INDNL .EQ. 4.

4. The bulk modulus (K) is computed according to the following equation:

$$K = MAX(K_1 * A_p * [-I_1'/(3 * A_p)]^{K_2}, K_{min})$$

   K_1 and K_2 are fitting parameters, A_p is atmospheric pressure and is used to obtain a dimensionless equation, and K_{min} is the minimum value of K which will control for small I_1'. K_{min} must be .GE. 0.

5. The shear modulus (G) is computed according to the following equation:

$$G = G_1 + G_2 * K$$

   G_1 and G_2 are fitting parameters.

6. AM and AC are defined in Fig. B.1.

7. AW and AD are material parameters for the hardening rule which is given by the following equation:

$$\varepsilon_v^p = AW*(exp(AD*X) - 1.]$$

   where X is the intersection of the cap with the I_1-axis. For large X, ε_v^p approaches AW.

8. R is the aspect ratio of the work-hardening elliptical cap. R is defined as the ratio of the horizontal to vertical axis of the ellipse.

9. XL .EQ. +1. for normally consolidated soil and the program calculates the initial cap position.

10. TENCUT is the maximum principal tensile strength. The material is assumed to fracture after reaching this value. For most test conditions in soil mechanics, the principal stresses remain compressive so the value of TENCUT is unimportant and it may be set .EQ. +1.

11. STATE is a material parameter which controls whether the cap is allowed to contract as well as expand.

12. A1 is the unit weight of soil. It must be 0 for use in CAP.

13. A2 is used to specify the initial vertical (Z-direction) stress (σ'_{vo}).

14. K_o is used to compute the initial horizontal (Y and X-directions) stress (σ'_{ho}) according to the following formula:

$$\sigma'_{ho} = K_o * \sigma'_{vo}$$

For hydrostatic (isotropic) initial conditions K_o = 1.0.

15. FAC is used to compute the bulk modulus of water (K_w) for use in undrained analysis:

$$K_w = FAC * K$$

FAC .EQ. 0. for drained analysis
.GT. 0. for undrained analysis; computes both positive and negative excess pore pressures
.LT. 0. for undrained analysis; computes only negative (compressive) excess pore pressures; positive pore pressures set .EQ. 0.

FAC .EQ. 10. has been found suitable for undrained analysis of soil mechanics problems.

16. PROP(18), PROP(20), PROP(21), and PROP(22) are not used by CAP and must be 0.

17. The strain path may be specified and CAP will compute the resulting stresses or the stress path may be specified and CAP will compute the resulting strains. The format of the remaining cards depends on the option chosen. 'strain' or 'stress' should be input in lower case without the quotes.

18. This card is used if the strain path is specified. It should be repeated for each set of applied strain increments. Smaller increments should be used as failure is approached. It may be necessary to adjust the strain increments based on the approximate failure strain indicated by a preliminary run.

    For axisymmetric conditions (ITYP2D .EQ. 0) $\Delta\varepsilon_{yy}$ = $\Delta\varepsilon_{xx}$. For plane strain conditions (ITYP2D .EQ. 1) $\varepsilon_{xx} = \Delta\varepsilon_{xx} = 0$.

19. w accounts for rigid body motion (McCarron, 1985); it is not accounted for in most soil mechanics tests and may be taken as 0.

20. This card and the following card are used if the stress path is specified. RTOL .EQ. 0.005 and ITEMAX .EQ. 20 are suitable for many test conditions encountered in soil mechanics.

21. IREF specifies the number of times the stiffness matrix will be reformed if the solution does not converge in ITEMAX iterations. If the solution still does not converge after IREF reformations execution is terminated.

22. This card should be repeated for each set of applied stress increments. Smaller increments should be used as failure is approached. It may be necessary to adjust the stress increments based on the approximate failure stress indicated by a preliminary run. In general KSWTCH .EQ. 0 except for first increment of an unloading sequence that would cause movement of the state of stress from the cap or Drucker-Prager surface into the elastic region in which case KSWTCH .EQ. 1.

    For axisymmetric conditions (ITYP2D .EQ. 0) $\Delta\sigma_{yy}$ = $\Delta\sigma_{xx}$. For plane strain conditions (ITYP2D .EQ. 1) $\Delta\sigma_{xx} = 0$.

APPENDIX C

AUTOGEN
PREPROCESSOR FOR PS-NFAP

AUTOGEN
PREPROCESSOR FOR PS-NFAP

by W. O. McCarron and W. F. Chen
with revisions by D. N. Humphrey

AUTOGEN is a preprocessor for use with PS-NFAP. It assists in preparation of the input file for PS-NFAP by generating the nodal coordinates, two-dimensional element data, and initial nodal loads. The program is written in FORTRAN IV. It is implemented on an IBM-PC using the Ryan-McFarland FORTRAN compiler version 2.0, and an IBM 3083 mainframe using VS-FORTRAN. Program input is read from standard input (unit 5) and the output is written to a file named NFINP (assigned to unit 8). This file is then used as input to PS-NFAP. If necessary, a text editor can be used to modify NFINP prior to use with PS-NFAP. NFINP contains some information applicable only to 3-dimensional problems such as the x-coordinate but this is ignored by PS-NFAP. A flow chart for the program is shown in Fig. C.1.

AUTOGEN commands are separated into three categories: JOINT, ELEMENT, and LOAD commands. The global categories should appear in the order:

JOINT
ELEMENT
LOAD

The ELEMENT and LOAD commands may be separated into groups to accommodate different 2-D element groups in PS-NFAP. However, the LOAD commands will act upon only those elements defined in the immediately preceding ELEMENT command. There are several options within each category and these may appear in any order.

Two auxiliary commands are available which allow cards not generated by AUTOGEN to be incorporated at the appropriate place in NFINP. The command NFAP causes the immediately following cards to be copied directly into NFINP as they appear and in the position they appear. The cards are copied to NFINP until a JOINT, ELEMENT, or LOAD command is encountered. The command FOLL has the same function as NFAP, except that it is used to append the last group of cards to the end of NFINP. A FOLL command and any cards to be appended to NFINP must be the final card sequence in the AUTOGEN INPUT file.

Input instructions are given in Appendix C.1. All input is formatted. Sample inut and output is given in Appendix E.

```
OPERATION                   SUBROUTINE       SUBROUNTINES CALLED

READ FIRST CARD             MAIN

EXECUTE JOINT COMMANDS      JOINT ------------------------------JTGE
                                                                  |
EXECUTE ELEMENT COMMANDS    ELEMNT -------------ELGEN            JTDUP
                                                  |                |
EXECUTE LOAD COMMANDS       LDGEN  ----DERIQ    ELDUP            JTFI
                                         |        |                |
COMPLETE NFAP DECK          OUTPT      FUNCT2   ELSTRG           MSHG
                                         |        |                |
STOP                        MAIN       OUTPT    EMB2             EMB2
                                                  |                |
                                                REDEF            OUT
                                                  |
                                                OUTPT
```

Fig. C.1 AUTOGEN Flowchart.

APPENDIX C.1

INPUT INSTRUCTIONS FOR AUTOGEN

FIRST CARD

INPUT : numjt, numel
FORMAT : (2I5)

Definitions:

numjt = Number of joints in the model.
numel = Number of two-dimensional elements in the model.

The remainder of the cards may be JOINT, ELEMENT, LOAD, NFAP, or FOLL cards as described below.

EXAMPLE

```
   15    8
```

JOINT COMMANDS

The joint definition cards and joint generation commands should be preceded by a JOINT header card. Any number of JOINT header cards may be present within the INPUT file. The various options available for joint generation are:

JTGEN : To generate a string of nodes from a previously defined anchor node.

JTDUP : To create a new set of nodes from a previously defined set of nodes.

MSHGEN : To generate a mesh of nodes beginning with a previously defined node.

EMB : To generate a mesh of nodes for an embankment model. Symmetry about the centerline is assumed, therefore, only half of the embankment is generated. A 2 to 1 (h/v) side slope of the embankment is assumed.

JTFIX : To specify the type of restraint for a group of nodes.

In some cases it may be convenient to redefine a node defined by a previous command. The most recent definition is retained.

JOINT HEADER and JOINT DEFINITION CARDS

JOINT DEFINITION CARDS : To define a nodal point

The JOINT header card may be followed by any number of JOINT DEFINITION cards.

INPUT : node, x, y, z
FORMAT : (1x,i4,3f10.0)

Definitions:

node = The node number.
x = X coordinate (leave blank).
y = Y coordinate.
z = Z coordinate.

EXAMPLE

```
joint
    1                    -2.       0.
    6                    -6.       3.
```

JTGEN : To generate a string of nodes from a previously defined anchor node.

INPUT : nn, numy, nincr, dy, dz
FORMAT : (1x,i4,2i5,2f10.0)

Definitions:

- nn = A previously defined node at which the node string will originate.
- numy = The total number of nodes in the string, including the original node.
- nincr = The nodal increment used to obtain the new node numbers.
- dy = The Y coordinate increment between nodes.
- dz = The Z coordinate increment between nodes.

EXAMPLE

```
jtgen
    1    3    1         0.        -1.
```

JTDUP : To create a new set of nodes from a previously defined set of nodes.

INPUT : nn, n2, nincr, dy, dz
FORMAT : (1x,i4,2i5,2f10.0)

Definitions:

- nn = The first node of the previously defined set.
- n2 = The last node of the previously defined set.
- nincr = The nodal increment used to obtain the new node numbers.
- dy = The Y coordinate increment.
- dz = The Z coordinate increment.

EXAMPLE

```
jtdup
    1    3    3         1.
    4    6    3         1.
    7    9    3         1.
   10   12    3         1.
```

MSHGN : To generate a mesh of nodes beginning with a previously defined node.

INPUT : nn, numy, nyi, dy, numz, nzi, dz
FORMAT : (1x,i4,2(2i5,f10.0))

Definitions:

- nn = The previously defined anchor node.
- numy = The total number of nodes in the Y direction.
- nyi = The node number increment in the Y direction.
- dy = The coordinate increment in the Y direction.
- numz = The total number of nodes in the Z direction.
- nzi = The node number increment in the Z direction.
- dz = The coordinate increment in the Z direction.

EXAMPLE

```
mshg
   1    9   14        6.    9    1       -3.
  10    8   14        6.    5    1       -6.
 143    4    8       12.    5    1       -6.
 148    3    8       12.    3    1      -12.
```

EMB : To generate a mesh of nodes for an embankment model. Symmetry about the centerline is assumed, therefore, only half of the embankment is generated. A 2 to 1 (h/v) side slope of the embankment is assumed.

INPUT : nn,nel,nlyrs,dy,elv
FORMAT : (3i5, 2f10.0)

Definitions:

nn = The number of the first node to be generated.
nel = The number of elements in the first row (default = 1)
nlyrs= The number of element layers in the embankment.
dy = Half the length of one element.
elv = The elevation of the first node.
= Elevation of top of embankment.

EXAMPLE

```
emb
    1    5    2.      0.
```

NOTES (1) This option may only be used once in the model.
(2) The mesh generated is for eight-noded elements.
(3) At least one joint must be defined prior to this command.
(4) Joint restraints in the y-direction along the axis of symmetry are automatically generated.
(5) The elements have dimensions 2dy in the y-direction and dy in the z-direction.
(6) The first node (nn) is located on the centerline at the top of the embankment.
(7) The usefulness of this option is limited if incremental construction of the embankment will be used in PS-NFAP since the resulting lift thickness is too large unless an excessively large number of elements are used.

JTFIX : To specify the type of restraint for a group of nodes

INPUT : iope, nfxy, nfxz, nd(i)
FORMAT : (1x,i4,15i5)

Definitions:

iope = 0 = Fix all nodes between consecutive pairs.
1 = Fix listed nodes.
2 = Fix nd(2) number of nodes beginning with nd(1) and having a nodal increment of nd(3)
nfxy = Type of restraint in the Y direction.
nfxz = Type of restraint in the Z direction.
nd(i) = The list of nodes, up to twelve on each card.

EXAMPLES

jtfix

0	1	0	1	3	13	15	
1	1	1	3	6	9	12	15
2	1	0	18	19	3		
2	1	1	23	18	3		

ELEMENT COMMANDS

The element commands are used to generate two-dimensional 4 to 8 node quadrilateral elements. The element definition and generation commands should be preceded by an ELEMENT header card. Any number of ELEMENT header cards may be present within the INPUT file. The various options available for element generation are:

ELDUP : To create a new group of elements from a previously defined group.

ELGEN : To create an element mesh from an existing element.

ELSTRG : To create a string of elements from an existing element.

EMB : To generate a mesh of elements for an embankment model. Symmetry about the centerline is assumed, therefore, only half of the embankment is generated. A 2 to 1 (h/v) side slope of the embankment is assumed.

REDEF : To redefine the nodal incidences of a string of elements

ELEMENT HEADER and ELEMENT DEFINITION CARDS

The ELEMENT header card may be followed by any number of ELEMENT DEFINITION cards.

ELEMENT DEFINITION CARDS

```
CARD 1    INPUT   : nn,ips,mtyp,beta,thic
          FORMAT  : (1x,i4,2i5,2f10.0)

CARD 2    INPUT   : (nd(i),i=1,8)
          FORMAT  : (8i5)
```

Definitions

```
CARD 1    nn      = The element number
          ips     = The stress output table (not used; enter 1)
          mtyp    = The material property number
          beta    = The orientation angle for orthotropic materials
                    (not used; leave blank)
          thic    = The element thickness for plane stress elements
                    (not used; leave blank)

CARD 2    nd(i)   = the node numbers that form the element = 0
                    if node position not used
```

EXAMPLE

```
eleme
    1    1    3
    1    2    5    4    0    0    0    0
```

ELDUP : To create a new group of elements from a previously defined group.

INPUT : nn, n2, neli, nji
FORMAT : (1x, i4, 3i5)

Definitions:

nn = The first element of the original group.
n2 = The last element of the original group.
neli = The element number increment used to obtain the new elements.
nji = The node number increment used to obtain the new elements.

EXAMPLE

```
eldup
    1    4    4    6
```

ELGEN : To create an element mesh from an existing element.

INPUT : nn, numy, neliy, ndiy, numz, neliz, ndiz
FORMAT : (1x, i4, 6i5)

Definitions:

nn = The previously defined anchor element.
numy = The total number of elements in the Y direction including anchor element.
neliy = The increment in element number in the Y direction.
ndiy = The node number increment in the Y direction.
numz = The total number of elements in the Z direction including anchor element.
neliz = The increment in element number in the Z direction.
ndiz = The node number increment in the Z direction.

EXAMPLE

```
elgen
    1    2    2    3    2    1    1
```

```
ELSTRG : To create a string of elements from an existing
         element.

         INPUT    : nn, num, neli, nd(i)
         FORMAT   : (1x, i4, 10i5)

Definitions:

    nn   = The original element.
    num  = The total number of elements in the string including
           the original.
    neli = The increment in the element number.
   nd(i) = An array of node number increments to be added to
           the corresponding node number of the element.

EXAMPLE

elstr
    1    4    1    2    2    2    2    1    2    1    2
```

EMB : To generate a mesh of elements for an embankment model. Symmetry about the centerline is assumed, therefore, only half of the embankment is generated. A 2 to 1 (h/v) side slope of the embankment is assumed.

```
CARD 1   INPUT  : nn,ips,beta,thick
         FORMAT : 2I5, 2f10.0

CARD 2   INPUT  : (mt(i),i=1,nlyrs)
         FORMAT : 16I5
```

Definitions:

```
nn    = The number to be assigned to the first element.
ips   = Stress printing option (not used; enter 1).
beta  = Element orientation for orthotropic material
        (not used; leave blank).
thick= Element thickness if plane stress option
        (not used; leave blank).
mt    = The material type to be assigned to each layer.
nlyrs= The number of element layers in the embankment.
```

EXAMPLE

```
emb
    1    1
    1    1    1    1    1
```

NOTES (1) This option may only be used once in the INPUT file.
(2) The elements generated are eight-noded elements.
(3) A least one element must be defined prior to using this command (a dummy element may be used which will be redefined by this command).

REDEF : To redefine the nodal incidences of a string of elements

INPUT : nn,n2,ni,(nd(i),i=1,8)
FORMAT : 1x,i4,2i5,8i5

Definitions:

nn = The first element of the string.
n2 = The last element of the string.
ni = The increment to be added to the substituted nodes nd(i).
nd = The array of nodes to be substituted for element "nn" (a zero entry causes the node's original definition to remain the same).

EXAMPLE

```
redef
  147  158   20    0    0    1   21    0    0   14    0
```

LOAD COMMANDS

AUTOGEN may be used to generate gravity loads or equivalent nodal loads to balance specified initial stresses. Naylor, et al. (1981), "Finite Elements in Geotechnical Engineering", contains a useful description of the methods available for specification of initial stresses and computation of the corresponding load vector. This option assumes that the ground surface is horizontal and has a z-coordnate (elevation) of 0.

```
CARD 1   INPUT   :  LOAD
         FORMAT  :  (a4)
CARD 2   INPUT   :  ldtyp,ngrp,ncury,ncurz
         FORMAT  :  (4i10)
```

Definitions:

```
ldtyp = 1 To generate body force or gravity loads.
      = 2 For in-situ loads (y direction only).
      = 3 For in-situ loads (y and z direction).
      = 4 For in-situ loads (z direction only).
      = 5 To generate a z-direction unit load for the
          nodes in an element.

ngrp  =   The number of element groups
          (ngrp number of Card 3 must be provided).
ncury =   Load curve number for y-dir loads (default = 1).
ncurz =   Load curve number for z-dir loads (default = 1).
```

If ldtyp = 1

```
CARD 3   INPUT   :  n1,n2,bf,nnintz,idir
         FORMAT  :  (2i10,f10.0,i10)
```

Definitions:

```
n1    = First element number of this group; default = 1.
n2    = Last  element number of this group; default = numel.
bf    = Body force (weight of soil).
nnint = Order of gauss quadrature, default = 2.
idir  = Direction of load, default = 3.
      = 2  y direction.
      = 3  z direction.
```

If ldtyp = 2

Same as ldtyp = 3 except only z-direction equivalent loads are computed.

LOAD COMMANDS (CONTINUED)

If ldtyp = 3

```
CARD 3   INPUT   :  n1,n2,a1,a2,xk,nnint
         FORMAT  :  (2i10,3f10.0,i10)
```

Definitions:

```
   n1     = First element number of this group; default = 1.
   n2     = Last  element number of this group; default = numel.
   a1,a2  = Coefficients used to compute the initial stresses.
   xk
            sz = a1*z + a2
            sy = sz*xk
   nnint  = Order of gauss quadrature, default = 2.
```

If ldtyp = 4

Same as ldtyp = 3 except only z-direction equivalent loads are computed.

If ldtyp = 5

```
CARD 3   INPUT   :  n1,n2
         FORMAT  :  (2i10)
```

Definitions:

```
   n1      = First element number.
   n2      = Last  element number.
```

EXAMPLES

```
load
         3          1
         1          8        10.          0.          1.          2
load
         1          1
         1          8       -10.           2
```

APPENDIX D

PS-NFAP
FE PROGRAM TO ANALYZE PLANE STRAIN PROBLEMS WITH THE CAP SOIL MODEL

INTRODUCTION

PS-NFAP is a finite element (FE) computer program for analysis of plane strain problems using the cap strain-hardening model to represent soil behavior. It is capable of analyzing embankments constructed on soft ground and has special features which allow analysis of reinforced embankments. PS-NFAP was adapted by Humphrey (1985) from a general purpose FE program called NFAP that was originally developed by Chang (1980). The cap model was implemented in NFAP by McCarron (1985) and McCarron and Chen (1986a, 1986b). PS-NFAP is written primarily in FORTRAN IV although some sections of the code use features of FORTRAN77. It is implemented on an IBM-PC using Ryan-McFarland FORTRAN, version 2.0 (Ryan-McFarland, 1985) and on an IBM 3083 mainframe using VS-FORTRAN. The program uses the convention that compressive stresses and strains are negative. Since most stresses encountered in soil mechanics are compressive, most stresses for analysis of soils problems with PS-NFAP will be negative.

This appendix is organized as follows. The general capabilities of PS-NFAP are described in the next section; then program organization is outlined. Next program operation is described. Input instructions are given in Appendix D.1 and comments to the input instructions are given in Appendix D.2. An example illustrating use of PS-NFAP to analyze a reinforced embankment constructed on soft ground is given in Appendix E.

CAPABILITIES OF PROGRAM

PS-NFAP performs an incremental load-displacement analysis. After each increment of load is applied the displacement field is modified using an iterative procedure until an equilibrium configuration is reached. Convergence is based on the difference between two successive displacement norms as defined in Section 5.2 of Humphrey and Holtz (1986).

Two element types are included in PS-NFAP. The first is a two or three node TRUSS element which can carry only axial load. Material behavior is either linear elastic or nonlinear elastic. This element is used primarily to represent tensile reinforcement. There is an option that allows the element to be initially inactive and then subsequently activated at a specified load step. This can be used to simulate one or more reinforcing layers placed in an embankment during construction at a level above the original ground surface.

The second element type is a two-dimensional (2-D), 4 to 8-node, isoparametric, plane strain continuum element. It is used mainly to represent the foundation soil and embankment fill. Soil behavior is represented by the cap

model. The problem can be formulated considering only material nonlinearity or with an updated Lagrangian formulation. The latter expresses equilibrium equations in terms of the most recent equilibrium configuration and accounts for both geometric (large displacement) and material nonlinearities (McCarron, 1985). Details of the cap model are given in McCarron (1985) and Chen and Baladi (1985) and procedures to determine the cap parameters are given in Humphrey and Holtz (1986). The model allows initial stresses to be specified. The element can be initially inactive and then activated at a specified load step. This is useful to simulate lift by lift embankment construction. Behavior can be drained or undrained. There is an option which allows behavior to be switched from drained to undrained at a specified load step. This has been used to establish the initial state of stress for an existing embankment on a fully consolidated foundation prior to placement of additional fill under undrained conditions (Humphrey and Holtz, 1986). The 2D element also has a linear elastic material behavior model.

In addition, PS-NFAP has a routine to renumber the nodes to minimize the band width of the stiffness matrix, thereby, improving solution efficiency. In the IBM-PC version, this is implemented as a separate program called RENUMX. There is also an out of core equation solver that permits solution of large problems on computers with limited memory. Solution results can be saved for use as the starting point of a restart job in which additional load steps are applied.

PROGRAM ORGANIZATION

PS-NFAP is comprised of a MAIN program that calls subroutine NFAP which controls the remainder of the execution. The 57 subroutines used in the main portion of PS-NFAP are listed in Table D.1 along with a short description of their purpose. The subroutines used in the node renumbering portion of the program are listed in Table D.2. There is also a BLOCK DATA unit.

Program operation can be separated into input, solution, and equilibrium iteration phases. An outline of the operations performed in each phase is given in McCarron and Chen (1986a). A simplified flow chart of PS-NFAP operation is shown in Fig. D.1. Some of the input data, intermediate calculations, and solution results are stored in a large matrix called the 'A-matrix' which is assigned to blank common. Other data is temporarily stored in files for use during subsequent load steps. File usage is summarized in Table D.3.

PROGRAM OPERATION

Input instructions are given in Appendix D.1 and comments to the input instructions are given in Appendix D.2. The input file is assigned to standard input (unit 5) and results are output to standard output (unit 6). Example input and output files are shown in Appendices E.3 and E.5, respectively.

IBM-PC Version

The IBM-PC version runs on IBM-PC, IBM-XT, IBM-AT, or compatible computers with at least 512K of memory and a hard disk. More memory, up to the system limit of 640K, is desirable for larger problems. The first step in running PS-NFAP, if the node renumbering option is chosen, is to run the node renumbering program NFMINX. It is executed with the following command:

```
C>NFMINX /R 20000 <FILE.NF1 >FILE.NMO
```

where C> is the PC-DOS prompt, /R 20000 reserves 20K of memory for records from unformatted read and write statements (Ryan-McFarland, 1985), FILE.NFI is the PS-NFAP input file, and FILE.NMO is the output file. A list of the renumbered nodes is written to FILE.NMO and to a file named NFMIN.NFP for later use by PS-NFAP. An example output is shown in Appendix E.4.

Next PS-NFAP is invoked with the following command:

```
C>PSNFAP /R 63735 <FILE.NFI >FILE.NFO
```

where /R 63735 reserves 63.7K of memory for records from unformatted read and write statements (Ryan-McFarland, 1985) and FILE.NFO is the output file. An example output is shown in Appendix E.5. For large problems the temporary scratch files listed in Table D.3 and FILE.NFO require considerable disk storage in some cases exceeding 1 megabyte. The user should check that there is sufficient disk storage prior to execution of PS-NFAP.

If it is necessary to recompile PS-NFAP using the Ryan-McFarland (1985) compiler the /I option should not be used. This causes the default size of all integers to be INTEGER*4 (32 bits). Subroutine ASSEM only should be compiled with the /b option to generate code to access arrays larger than 64K.

Size of A-matrix

Large problems can be run most efficiently if there is sufficient space in the A-matrix to allow the solution to be performed completely in core. However, the maximum size of

the A-matrix may be limited by the computer system. On an IBM-PC with 640K of memory the maximum size is 72000.

The size of the A-matrix can be changed if necessary. In the mainframe version this is done by changing the size of the A-matrix and the variable MTOT in the main program, recompiling the main program, and then relinking the program. Note that the size of the A-matrix is MTOT + 10. In the IBM-PC version the size is changed by altering the size of A, IA, and MTOT in the file named A.CMM which is shown below:

```
      COMMON A(72010)
      DIMENSION IA(72010)
      EQUIVALENCE (A(1),IA(1))
      MTOT = 72000
```

Note that the size of A and IA are 10 greater than the size of MTOT. The following program units which contain the A-matrix are then recompiled: EL2D10, ELCAL, LSTM, MAIN, NFAP, NFAPIN, RUSS, STRCAL, TDFE, TODMFE, and TRUSS using the batch file RECOMA.BAT listed in Table D.4. The entire program is then linked using the link file PSNFAP.LNK listed in Table D.5 in conjunction with the Ryan-McFarland linker using the command shown below (Ryan-McFarland, 1985):

```
C>PLINK86 @PSNFAP
```

REFERENCES

1. Chang, T. Y. (1980), A Nonlinear Finite Element Analysis Program - NFAP, User's Manual, Vol. 2, Department of Civil Engineering, The University of Akron, Akron, Ohio.

2. Chen, W. F., and Baladi, G. Y. (1985), Soil Plasticity-Theory and Implementation, Elsevier Science Publishing Co., New York, 231 pp.

3. Humphrey, D. N. (1985), Task 4 - Development of a Simplified FEM Program - Progress Report, Unpublished report, School of Civil Engineering, Purdue University, West Lafayette, IN 47907, 10 pp.

4. Humphrey, D. N., and Holtz, R. D. (1986), "Design of reinforced embankments," Joint Highway Research Project Report, School of Civil Engineering, Purdue University, West Lafayette, IN 47907.

5. McCarron, W. O. (1985), Soil Plasticity and Finite Element Applications, PhD. Thesis, School of Civil Engineering, Purdue University, West Lafayette, IN 47907, 266 pp.

6. McCarron, W. O., and Chen, W. F. (1986a), "NFAP operations and organization," Structural Engineering Report CE-STR-86-1, School of Civil Engineering, Purdue University, West Lafayette, IN 47907, 18 pp.

7. McCarron, W. O., and Chen, W. F. (1986b), "NFAP - User's manual (1986 Purdue version)," Structural Engineering Report CE-STR-86-4, School of Civil Engineering, Purdue University, West Lafayette, IN 47907, 210 pp.

8. Ryan-McFarland (1985), RM/FORTRAN User's Guide, Version 2, Ryan-McFarland Corporation, Rolling Hills Estates, CA 90274.

Table D.1
PS-NFAP subroutines

ACTRED	Equation solution
ADDBAN	Save element stiffness on tape & assemble load vector
ADDMAT	Assemble element stiffness matrices into global stiffness matrix
ADDRES	Calculate addresses of diagonal elements in banded matrix
ASBLK	Assemble element blocks
ASOLVE	Equation solution; Choleski decomposition of profile stored in symmetric matrix
ASSEM	Assembles nonlinear stiffness matrix
BACSUB	Equation solution
CAUCHY	Convert Piola-Kirkhhof stresses to Cauchy stresses
COLHT	Computes column height of banded matrix
DERIQ	Evaluates strain-displacement matrix for quadrilateral element
DEVPRT	Computes deviatoric stresses
DOT1	Computes vector dot product
EL2D10	CAP model
ELCAL	Input element data
ELEMNT	Calls routines for reading, generating and storing element data
EP2D10	CAP model
EPL210	CAP model
EQUIT	Equation solution; equilibrium iteration
FUNCT2	Finds interpolation functions and derivatives for 4- to 8-node isoparametric quadrilateral; finds Jacobian and its determinant
FUNCTC	Finds interpolation functions for 2- or 3-node truss elements
GRAV	Computes gravity force during incremental embankment construction
IEP210	Initializes working array for CAP model
INITAL	Saves ID array and initializes displacements to zero
INITWA	Calls subroutines to initialize working array for 2 dimensional material models
INPUT	Input, generate and print nodal data; compute equation numbers (ID array)
LOADEF	Calculate effective loads for nonlinear elements and updates load vector calculated in LOADVC
LOADS	Reads load curves and nodal load data; calculates load vector for each time step
LOADVC	Calls NFAPIN to read and calculate load vectors
LSOLVE	Equation solution
LSTM	Assembles linear stiffness

Table D.1
PS-NFAP subroutines (cont.)

MATBAR	Material model for truss element
MATRT2	Print material properties for quadrilateral element
MAXMIN	Computes principal stresses
MD2D10	CAP model; develops elastic-plastic stress-strain relation if loading occurs on CAP
MKBLK	Sets up blocks for equation storage
MULT	Equation solution; computes product of blocked matrix and vector
NEWDAV	Calculates new displacements at time T+delta(T)
NFAPIN	Reads input data
PFILE	Equation solution; reads and writes records to tape
PLACE	Updates current displacement
PRAGER	Forms elasto-plastic material matrix for Drucker-Prager yield criterion
QUADC	Computes element stiffness and stresses for truss element
QUADS	Computes element stiffness for isoparametric quadrilateral element
RSTART	Saves data for restart job
RUSS	Truss element
SECOND	Monitors elapsed time (IBM-PC version only)
SIZE	Check of storage requirements
STRCAL	Calculate maximum block size and determine if in core or out-of-core solution scheme must be used
STRESS	Calculates nodal stresses
STSTL	Generate global stress-strain law for isotropic, linear materials in plane strain
STSTN	Generate global stress-strain law and stresses for nonlinear material models
SUMLD	Computes and prints loading function table
TDFE	Quadrilateral element
TODMFE	Quadrilateral element
TRUSS	Truss element
WRITE	Prints displacements

Table D.2
Subroutines used for
nodal numbering optimization

BAND	NINCON
CHECK	NMBER
DELETE	PIKLVL
DGREE	PROFIT
ELSTR	REDUCE
FNDIAM	SETAP
FORMLV	SORT2
GIBB	SORTDG
LINK	TREE
NFPMIN	

Table D.3
File usage by PS-NFAP

File no.	Subroutines referenced	Information stored in file
1	ASSEM,ELCAL,STRESS	Linear element group data
2	ASSEM,ELCAL,EQUIT, RSTART,STRESS	Nonlinear element group data
3	EQUIT,LOADEF,LOADS, NFAP	Externally applied loads
4	ADDBAN,ASBLK,EQUIT, MULT,NFAP,PFILE	(1.) Linear element stiffness matrix,element by element (2.) Linear structural stiffness in blocks
8	INITAL,LOADS,NFAP, RSTART,WRITE	(1.) ID array and initial displacement (2.) ID array, displacement and displacement increments for restart File is named TAPE8
9	ASSEM,EQUIT,RSTART, STRESS	Same as file 2 and nonlinear group data for restart File is named TAPE9
10	EQUIT,NFAP,PFILE	Effective nonlinear stiffness in blocks
12	ADDBAN,ASBLK,PFILE	Global stiffness matrix in blocks
14	MKBLK,PFILE	Designated block structure for assemblage
18	PFILE	Element stiffness before assemblage
20	NFAPIN,GIBB	Renumbered nodes in file named NFMIN.NFP (IBM-PC version only)

Note: Files 1, 2, 3, 4, 10, 12, 14, and 18 are scratch files and are not saved at the end of program execution.

Table D.4
Batch file RECOMA.BAT to recompile subroutines
when size of A-matrix is modified

```
===============================================================
REM   BATCH FILE TO RECOMPILE SUBROUTINES WHEN SIZE OF
REM   A-MATRIX MODIFIED
REM
RMFORT EL2D10 /L >EL2D10.LST
RMFORT ELCAL  /L >ELCAL.LST
RMFORT LSTM   /L >LSTM.LST
RMFORT PSNFAP /L >PSNFAP.LST
RMFORT NFAPS  /L >NFAPS.LST
RMFORT NFAPIN /L >NFAPIN.LST
RMFORT RUSS   /L >RUSS.LST
RMFORT STRCAL /L >STRCAL.LST
RMFORT TDFE   /L >TDFE.LST
RMFORT TODMFE /L >TODMFE.LST
RMFORT TRUSS  /L >TRUSS.LST
===============================================================
```

Table D.5
Link file PSNFAP.LNK to link PS-NFAP

```
===============================================================
FILE PSNFAP,BLKDATA,NFAPS,RSTART,SIZE,SECOND
FILE ADDRES,ELCAL,ELEMNT,INITAL,INPUT,LOADS,LOADVC
FILE LSTM,MKBLK,NFAPIN,STRCAL,ACTRED
FILE ADDBAN,ADDMAT,ASBLK,ASOLVE,ASSEM,BACSUB,COLHT,DERIQ
FILE DOTI,EQUIT,LOADEF,LSOLVE,MULT,NEWDAV,PFILE,PLACE,STRESS
FILE SUMLD,WRITE
FILE CAUCHY,INITWA,MATRT2,MAXMIN,QUADS,STSTL,STSTN
FILE TDFE,TODMFE
FILE DEVPRT,EL2D10,EP2D10,EPL210,FUNCT2,GRAV,IEP210
FILE MD2D10,PRAGER
FILE FUNCTC,MATBAR,QUADC,RUSS,TRUSS
OUTPUT PSNFAP
===============================================================
```

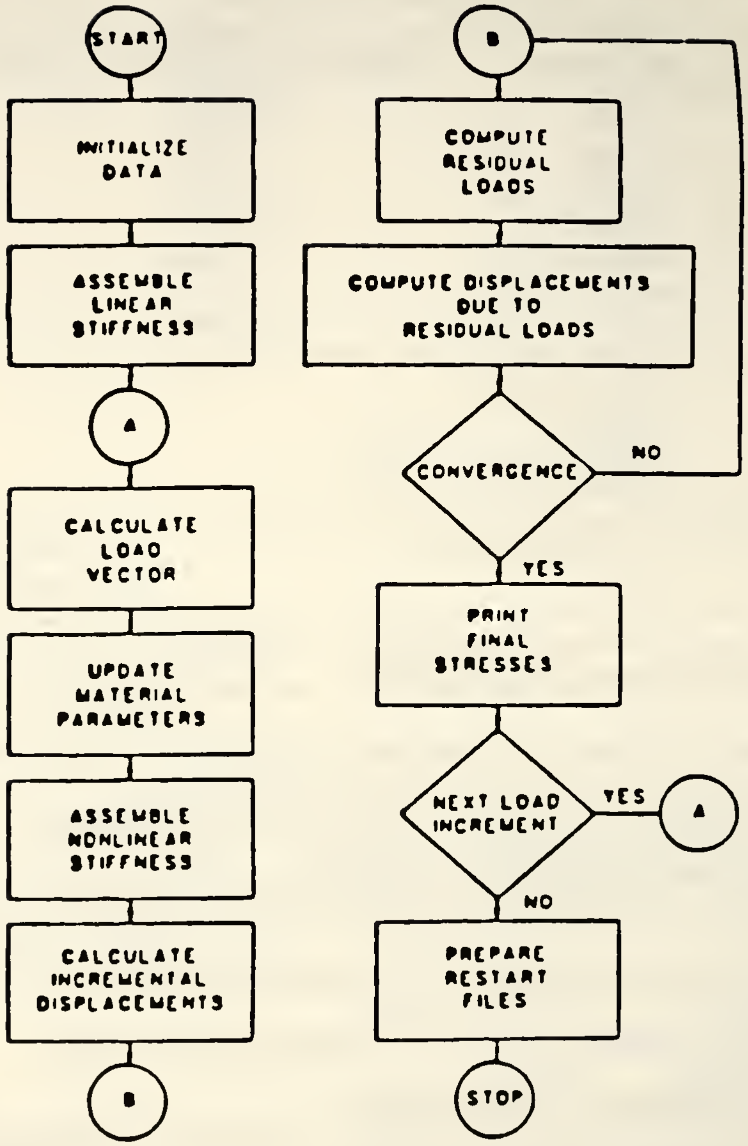


Figure D.1. PS-NFAP flowchart.

APPENDIX D.1

INPUT INSTRUCTION

EADING

ard 1.1

olumns	Variable	Comment*	Entry
- 72	HED (18)	(1)	Enter the master heading information for use in labeling the output

Detailed comment on the definition of variable can be found in APPENDIX D.2.

MASTER CONTROL CARDS

Card 2.1

Columns	Variable	Comment	Entry
1-5	NUMNP	(1)	Total number of nodal points; EQ.0; program stop
12-15	NEGL	(2)	Number of linear element groups; EQ.0; all elements are nonlinear
16-20	NEGNL	(3)	Number of nonlinear element groups; EQ.0; all elements are linear
21-25	MODEX	(4)	Flag indicating solution mode; EQ.0; data check EQ.1; execution EQ.2; restart
26-30	NPER	(5)	Number of different solution time periods
31-35	IPRI	(6)	Output printing interval; EQ.0; default set to "1"
36-40	IRINT	(7)	Restart save time step interval EQ.0; no saving for restart GT.0; interval for data saving
46-50	ISTOTE	(8)	Specified block size EQ.0; calculated automatically by the program
51-55	NRENUM	(9)	Flag indicating node renumbering to minimize column height of stiffness matrix EQ.0; no node renumbering EQ.1; node renumbering

MASTER CONTROL CARDS (continued)

Card 2.2

Columns	Variable	Comment	Entry
1-5	ISREF	(1)	Number of steps between re-forming effective stiffness matrix EQ.0; default set to 1
6-10	NUMREF	(2)	Number of iterations between stiffness reformation each time step EQ.0; no reformation
11-15	IEQUIT	(3)	Number of time steps between equilibrium iterations EQ.0; default set to 1
16-20	ITEMAX	(3)	Maximum number of equilibrium iterations permitted in each time step EQ.0; default set to 15
21-25	IACC		Flag indicated on acceleration scheme used during equilibrium iteration EQ.0; no acceleration EQ.1; secant acceleration
41-45	RTOL	(3)	Relative tolerance used to measure displacement convergence EQ.0; default set to "1.E-3"
46-50	FTOL	(3)	Relative force tolerance used to measure equilibrium convergence EQ.0; default set to "0".

MASTER CONTROL CARDS (continued)

Card 2.3

Columns	Variable	Comment	Entry
1-10	TSPER(1)	(1)	Starting time for 1st period
11-20	DTPER(1)	(1)	Time step increment for 1st period
21-30	TSPER(2)		Starting time for 2nd period
31-40	DTPER(2)		Time step increment for 2nd period
...	. . .		. . .
...	. . .		. . .
71-80	DTPER(4)		Time step increment for 4th period
Next card	(if required)		
1-10	TSPER(5)		Starting time for 5th period
1-20	DTPER(5)		Time step increment for 5th period
...	. . .		. . .
...	. . .		. . .
	TFINAL	(2)	Final time of analysis

MASTER CONTROL CARDS (continued)

Card 2.4

Columns	Variable	Comment	Entry
1-5	NPB	(1)	Number of blocks of displacement printout. EQ.0; print all nodal point components
6-10	IDC	(2)	Displacement printout code EQ.0; no displacement printout EQ.1; print displacements
21-25	IDSET	(3)	A reference node for displacement control of ghost elements

MASTER CONTROL CARDS (continued)

Skip this card if NPB.EQ.0

Card 2.5

Columns	Variable	Comment	Entry
1-5	IPNODE(1,1)	(1)	First node of printout block No. 1
6-10	IPNODE(2,1)		Last node of printout block No. 1
11-15	IPNODE(1,2) etc.		First node of printout block No. 2

NODAL POINT DATA

Card 3.1

(Input as many cards as required for all nodes)

Columns	Variable	Comment	Entry
2-5	N	(1)	Node (joint) number: GE.1 and LE.NUMNP
6	PSF	(2)	Print suppression flag (ignored unless N.EQ.1); EQ. ; (blank) no suppression EQ.A; suppress the list of nodal coordinates EQ.B; suppress the list of equation numbers EQ.C; both A and B above EQ.D; suppress the list of generated nodal coordinates
11-15	ID(2,N)	(3)	Y-translation boundary code
16-20	ID(3,N)		Z-translation boundary code
46-55	Y(N)		Y-coordinate
56-65	Z(N)		Z-coordinate
66-70	KN	(4)	Node number increment for node data generation; EQ.0; no generation

LOAD CONTROL CARDS

Card 4.1

Columns	Variable	Comment	Entry
1-5	NLOAD	(1)	Number of nodal force components to specify nodal forces
6-10	NLCUR	(2)	Total number of load curves (time functions)
11-15	NPTM	(2)	Maximum number of points used to describe any one of the load curves
41-45	NTURNS	(3)	Number of reverse load

LOAD CONTROL CARDS (continued)

Skip this card if NTURNS.EQ.0

Card 4.2

Columns	Variable	Comment	Entry
1-10	TRV(1)	(1)	Time of the first load reverse point
11-20	TRV(2)		Time of the second load reverse point
21-30	TRV(3)		Time of the second load reverse point
-----	------		---------------------------------------
71-80	TRV(8)		Time of the eighth load reverse point

Input NTURNS points; use additional cards as required.

ELEMENT LIBRARY

Element type is identified by the first entry (NPAR(1)) of the first card in this section, i.e.,

Element	NPAR(1)
Truss	1
2-D element	2

A structure may be divided into several groups of elements, consisting of either linear groups, nonlinear groups or both. Input as many blocks of data in this section as there are total element groups. Total number of linear element groups (NEGL) are input first, and followed by the total number of nonlinear element groups (NEGNL).

In any one group all element input must be the same element type and analysis type; e.g. if nonlinear TRUSS elements are given as input, then all elements in this group must be nonlinear. Furthermore, in any one group, only one material model can be used, e.g., all elements in the group must be defined by the cap model. However, a number of different sets of material constants for a specific model can be used.

TRUSS ELEMENT

TRUSS elements are two or three-node members allowed arbitrary orientation in the Y, Z system. The TRUSS transmits axial force only, and in general is a six (6) degree of freedom element (i.e., two global translation components at each of the element nodes).

Card 5.1

Columns	Variable	Comment	Entry
1-4	NPAR(1)		Enter the number "1"
5-8	NPAR(2)	(1)	Number of TRUSS elements in this group: GE.1
9-12	NPAR(3)	(2)	Type of analysis EQ.0; linear analysis EQ.1; materially nonlinear only EQ.2; large displacement
56-60	NPAR(15)	(3)	Material model number EQ.1; linear elastic EQ.2; nonlinear elastic
61-64	NPAR(16)	(4)	Number of different sets of section/material properties GE.1
65-68	NPAR(17)	(5)	Number of material model constants per set EQ.1 if NPAR(15).EQ.1 GE.4 if NPAR(15).EQ.2

TRUSS ELEMENT (continued)

Input cards for linear elastic material and truss member properties. Two input cards are required. Skip this set of cards if NPAR(15).NE.1. Otherwise read NPAR(16) sets of cards.

Card 5.2a. Material number card

Columns	Variable	Comment	Entry
1-5	N		Material/section number GE.1; and LE.NPAR(16)

Card 5.2b. Property card

Columns	Variable	Comment	Entry
1-10	E(N)	(1)	Young's modulus
11-20	AREA(N)		Cross-sectional area
31-40	PINIT(N)		Initial axial force

TRUSS ELEMENT (continued)

Input cards for nonlinear elastic material and member property cards. Two or more input cards are required. Skip this set of cards if NPAR(15).NE.2, otherwise read NPAR(16) sets of cards.

Card 5.3a. Material number card

Columns	Variable	Comment	Entry
1-5	N		Material/section number GE.1 and LE.NPAR(16)
11-20	AREA(N)	(1)	Cross-sectional area
[illegible]1-40	PINIT(N)	(2)	Initial axial force
41-50	TIME-ON	(3)	Time element is activated

Card 5.3b. Stress-strain curve card (8F10.0)

Columns	Variable	Comment	Entry
1-10	PROP(1,N)	(4)	Strain at point 1, ε^1
11-20	PROP(2,N)		Strain at point 2, ε^2
.	.		.
.	.		.
.	.		.
	PROP(NCON/2,N)		Strain at point NCON/2
	PROP(NCON/2+1,N)		Stress at point 1, σ^1
	PROP(NCON/2+2,N)		Stress at point 2, σ^2
.	.		.
.	.		.
.	.		.
	PROP(NCON,N)		Stress at point NCON/2

TRUSS ELEMENT (continued)

Card 5.4

NPAR(2) elements must be input and/or generated in this section in ascending sequence beginning with "1".

Columns	Variable	Comment	Entry
1-5	M		TRUSS element number; GE.1 and LE.NPAR(2)
6-10	II	(1)	First Node
11-15	JJ	(1)	Second Node
16-20	KK	(1)	Third Node
21-25	MTYP		Material property set number; GE.1 and LE.NPAR(16)
26-30	IPS		Flag for printing axial stress in TRUSS element; EQ.1, no printing EQ.0, print element stress
31-35	KG	(2)	Node generation increment used to compute node numbers for missing elements; EQ.0; default set to "1"

2-D CONTINUUM ELEMENT

Card 6.1

Columns	Variable	Comment	Entry
1-4	NPAR(1)		Enter the number "2"
5-8	NPAR(2)	(1)	Number of 2-D CONTINUUM elements in this group: GE.1
9-12	NPAR(3)	(2)	Flag indicating type of analysis EQ.0; linear analysis EQ.1; material nonlinear analysis only EQ.4; updated Lagrangian (large rotation)
25-28	NPAR(7)	(3)	Maximum number of nodes used to describe any one element: GE.4 and LE.8 EQ.0; default set to "8"
37-40	NPAR(10)	(4)	Numerical integration order to be used in Gauss quadrature formula: EQ.0; default set to "2" GE.2 and LE.4
57-60	NPAR(15)	(5)	Material model numbers: EQ.1; linear isotropic EQ.10; cap model with Drucker-Prager Shear limitation
61-64	NPAR(16)	(5)	Number of different sets of material properties: GE.1
65-68	NPAR(17)	(5)	Number of constants per property set; EQ.0; if NPAR(15).EQ.10 EQ.22;if NPAR(15).EQ.10
69-72	NPAR(18)	(5)	Dimension of storage array required for element history; EQ.0; if NPAR(15).EQ.1 EQ.12;if NPAR(15).EQ.10

2-D-CONTINUUM ELEMENT

NPAR(16) sets of Card 6.2 and Card 6.3 must be input. Card 6.2 is the same for all material models, but Card 6.3 depends on the material model number (NPAR(15)); choose from Card 6.3.1 or Card 6.3.10.

Card 6.2

Columns	Variable	Comment	Entry
1-5	N		Material property set number; GE.1 and LE.NPAR(16)

2-D CONTINUUM ELEMENT

Card 6.3.1 - Linear isotropic - NPAR(15).EQ.1

Columns	Variable	Comment	Entry
1-10	PROP(1,N)	(1)	Young's modulus, E
11-20	PROP(2,N)		Poisson's ratio, ν

2-D CONTINUUM ELEMENT

Card 6.3.10 - Soil Plasticity Cap Model
NPAR(15).EQ.10

Each Card Contains 8 input data. (8F10.0)

Columns	Variable	Comment	Entry
Card 8.3.10a			
1 - 10	PROP(1)	(1)	K_1
11 - 20	PROP(2)	(1)	K_2
21 - 30	PROP(3)	(1)	A_p
31 - 40	PROP(4)	(1)	K_{min}
41 - 50	PROP(5)	(1)	G_1
51 - 60	PROP(6)	(1)	G_2
61 - 70	PROP(7)	(2)	AM
71 - 80	PROP(8)	(2)	AC
Card 6.3.10b			
1 - 10	PROP(9)	(3)	AW
11 - 20	PROP(10)	(3)	AD
21 - 30	PROP(11)	(4)	R
31 - 40	PROP(12)	(5)	XL
41 - 50	PROP(13)	(6)	TENCUT
51 - 60	PROP(14)	(7)	STATE
61 - 70	PROP(15)	(8)	A_1
71 - 80	PROP(16)	(8)	A_2

2-D CONTINUUM ELEMENT

Card 6.3.10 (Continued)

Columns	Variable	Comment	Entry
Card 6.3.10c			
1 - 10	PROP(17)	(8)	K_0
11 - 20	PROP(18)	(9)	SWITCH
21 - 30	PROP(19)	(10)	FAC
31 - 40	PROP(20)	(11)	TIME-ON
41 - 50	PROP(21)	(12)	WGT
51 - 60	PROP(22)	(12)	BOUY

2-D CONTINUUM ELEMENT

Card 6.4a

(Two cards are needed for each element.)

Columns	Variable	Comment	Entry
1 - 5	M	(1)	2-D CONTINUUM element number; GE.1 and LE.NPAR(2)
6 - 10	IEL	(2)	Number of nodes used to describe this element; EQ.0; default set to "NPAR(7)" LE.NPAR(7)
16 - 20	MTYP		Material property set number assigned to this element; GE.1 and LE.NPAR(16)
21 - 25	KG	(1)	Node generation parameter used to compute node numbers for missing elements (given on first card of a sequence); EQ.0; default set to "1"

-D CONTINUUM ELEMENT (continued)

Card 6.4b

Columns	Variable	Comment	Entry
1 - 5	NOD(1)	(2)	Global node number of element nodal point 1
6 - 10	NOD(2)		Global node number of element nodal point 2
11 - 15	NOD(3)		Global node number of element nodal point 3
16 - 20	NOD(4)		Global node number of element nodal point 4
21 - 25	NOD(5)		Global node number of element nodal point 5
26 - 30	NOD(6)		Global node number of element nodal point 6
31 - 35	NOD(7)		Global node number of element nodal point 7
36 - 40	NOD(8)		Global node number of element nodal point 8

APPLIED LOADS

Supply NLCUR sets with 2 or more cards per set.

Card 7.1a (2I5)

Columns	Variable	Comment	Entry
1 - 5	NTF		Time function number; GE.1 and LE.NLCUR
6 - 10	NPTS		Number of points (i.e., f(t), t pairs) used to input this time function; GE.2 and LE.NPTM

Card 7.1b

Columns	Variable	Comment	Entry
1 - 10	TIMV(1)	(1)	Time at point 1, t_1
11 - 20	RV(1)		Function at point 1, $f(t_1)$
21 - 30	TIMV(2)		Time at point 2, t_2
31 - 40	RV(2)		Function value at point 2, $f(t_2)$
. . .	. . .		. . .
71 - 80	RV(4)		Function value at point 4, $f(t_4)$
Next card (if required)			
1 - 10	TIMV(5)	(2)	Time at point 5, t_5
11 - 20	RV(5)		Function value at point 5, $f(t_5)$
---	---	---	------------------------------

APPLIED LOADS

Skip this section of NLOAD.EQ.0

Card 7.2

Columns	Variable	Comment	Entry
1 - 5	NOD	(1)	Node number to which this load is applied: GE.1 and LE.NUMP
6 - 10	IDIRN		Direction of the load component; EQ.2; Y-translation EQ.3; Z-translation
11 - 15	NCUR		Load curve number that describes the time dependence of the load; GE.1 and LE.NLCUR (Default = 1)
16 - 25	FAC		Function multiplier used to scale f(t) for the load at "t"; EQ.0.0; default set to "1.0"
26 - 30	KN	(2)	Node increment for nodal load data generation EQ.0; no generation

APPENDIX D.2

INPUT DATA DESCRIPTION

EADING CARD

(1) Begin each data case with a heading card.

MASTER CONTROL CARDS

Card 2.1

1. The total number of nodes (NUMNP) controls the amount of data to be read in Section III. If NUMNP.EQ.0, the program terminates execution.

2. The program distinguishes between linear and nonlinear elements. Linear elements have their stiffness matrices formed only once, and the formulation excludes consideration of either geometric or material nonlinearities; linear elements are used to represent those regions of a model which can be assumed to behave linearly and should be used (where possible) to improve solution efficiency.

   An element group is a series of elements of a particular type (e.g., TRUSS or 2-D CONTINUUM) in which element numbers are assigned in ascending sequence beginning with "1" and ending with the total number of elements in that particular group. Elements forming a group must have the same

   a. Element type (NPAR(1)

   b. Type of analysis (NPAR(3))

   c. Material model (NPAR(15))

   d. Integration order (NPAR(10))

   Elements defined by the same values of the parameters listed above can be broken down into more than one group. This reduces solution efficiency but may be necessary to restrict the size of 2-D continuum element groups when PS-NFAP is run on an IBM-PC.

   It is emphasized that only one type of material model is allowed for the elements in a group (either linear or nonlinear). Also, it is permissible to model a structure with nonlinear elements only, in which case NEGL.EQ.0 and NEGNL.GE.1. Linear element groups are input before nonlinear groups in Card Group 5.

MASTER CONTROL CARDS (Card 2.1 continued)

3. Nonlinear elements include the effects of material and/or geometric nonlinearities in the formation of stiffness and stress recovery matrices. The type of nonlinearities to be associated with an individual group of elements is defined by means of data given on the element group control card. In separating elements into nonlinear groups, note that only one type of material model is allowed for the group. The order in which groups are input was discussed in Note (2) above.

   The total number of element groups processed by the program is the sum NELG+NEGNL. Also, NEGNL can be zero, but then the number of linear element groups must be at least one.

4. The MODEX parameter determines whether the program is to check the data without executing an analysis (i.e. MODEX.EQ.0) or if the program is to perform an analysis. The user has the following choices:

   MODEX = 0 Data check; the program will only read, check, and print input data.
   1 Perform analysis for a new problem.
   2 Perform analysis for a restart job.

5. NPER is the number of time periods which have the same time step incrments, NPER must be at least one. NSTE is the number of total solution (or load) steps, which is calculated by the program based on TFINAL.

6. The print interval determines at which solution step interval program results are to be printed. If IPRI.EQ.4, output is produced at the end of solution steps 4, 8, 12, etc.

   If IPRI is larger than the total number of solution steps (NSTE), then no output will be printed during the course of solution. If IPRI.LE.NSTE, then print directives must be given for displacements on Card 2.4 in this section.

MASTER CONTROL CARDS (Card 2.1 Continued)

7. IRINT specifies the time step interval for which the histories will be saved for restart. If IRINT.EQ.1 the histories are saved at the end of each solution step. This option is useful for solving large scale problems.

8. ISTOTE is a parameter which specifies the maximum block size to be used for out-of-core solution. If it is left blank, the program will determine the maximum block size. When operating on an IBM-PC with 640k of memory and an A matrix of size 72010, ISTOTE must be 15930 to limit the length of unformatted records written to disk.

9. NRENUM indicates the node-renumbering option. This minimizes the column height of the structure stiffness thereby improving solution efficiency. The node number is converted back to the original numbering scheme for the output. On an IBM-PC node renumbering is done by a separate program (NFMINX) and PS-NFAP reads the renumbered nodes from a file named 'NFMIN.NFP'.

MASTER CONTROL CARDS

Card 2.2

1. The stiffness matrix reformation interval (ISREF) is ignored if the model is composed of linear element groups only; i.e. NEGNL.EQ.0. For linear problems the matrix is formed and decomposed only once.

   For models containing nonlinear element groups, the system stiffness matrix is reformed every ISREF solution steps based on conditions known at the end of the previous step. For problems with nonlinear element groups using the cap material model ISREF.EQ.1, i.e., the system stiffness matrix is reformed at the start of every time step. Only the nonlinear portion of the complete system stiffness matrix is reformed; the linear portion is saved and reinstated when the complete matrix is calculated.

2. Stiffness reformation may also be requested during equilibrium iterations. When NUMREF.NE.0, this option is activated for every NUMREF cycles of iteration in each time step.

3. If a structure is represented by nonlinear element groups with material models which allow for equilibrium iteration such as the cap model, then the parameter IEQUIT determines at what solution step interval the program is to iterate for system equilibrium. ITEMAX is the maximum number of cycles of iteration allowed in the solution step and RTOL is used to measure convergence of the iteration in terms of change in system displacements. For example, if IEQUIT.EQ.5, ITEMAX.EQ.12 and RTOL.EQ.0.002, then providing the material model(s) allow for iteration, up to 12 cycles of iteration will be performed at solution steps 5, 10, 15, etc. with convergence declared if

$$\frac{||u^{(n-1)}|| - ||u^{(n)}||}{||u^{(n)}||}$$

   where $||u^{(n)}||$ is the Euclidean norm of the system displacement vector at cycle "n" of the iteration. For problems with nonlinear element groups using the cap model IEQUIT.EQ.1. ITEMAX.EQ.15 and RTOL.EQ.0.01 are satisfactory for solution of many cases of embankments constructed on soft ground. FTOL should be 0.0 for use with cap model.

MASTER CONTROL CARDS

Card 2.3

1. TSPER(I) is the time at which solution starts for each time period. This option provides the convenience to change time step size (DTPER(I)) for time dependent analysis. For a restart job, the starting time of the first time period would be the final time of the previous solution which was already run and saved on disk.

2. TFINAL is the final time of analysis for each run and it is used to calculate the total number of solution steps (NSTE).

MASTER CONTROL CARDS

Card 2.4

1. For large meshes it may not be necessary to print displacements at every node. Hence, nodes for which printout is desired are grouped into NPB printout blocks. Each block of nodes is defined by the node numbers of the first and last node in the block (see next card).

   If NPB.EQ.0 all nodal quantities are printed regardless of the values of IDC.

2. The displacements at the nodes within the blocks are printed if IDC.EQ.1.

3. If ghost elements are used (i.e., elements which are initially inactive), IDSET is used to update the Z-direction nodal coordintes during a large displacement analysis. IDSET=0 results in no update of the initial ghost element geometry. This feature is useful for problems that experience very large settlements.

MASTER CONTROL CARD

Card 2.5

1. Two entries are expected for each printout block, namely, the first node of the block and the last node of the block. All nodal points between these two nodes will be included in the printout block. Maximum of 8 printout blocks are allowed.

   Skip this card if NPB.EQ.0

NODAL POINT DATA

Card 3.1

1. Nodal data must be defined for all (NUMNP) nodes. Node data may be input directly (i.e., each node on its own individual card) or the generation option may be used if applicable (see note 5). Admissible node numbers range from "1" to total number of nodes (NUMNP). Node numbers may not be repeated or omitted. The last node that is input must be "NUMNP".

2. The print suppression flag (PSF) is used to eliminate printing of ordered node coordinates, equation number assignments, or generated node coordinates. The PSF character is entered on the first card of nodal point data only.

3. Boundary condition codes can only be assigned the following values (M = 2,3)
   ID(M,N) = 0; unspecified (free) displacement.
   ID(M,N) = 1; deleted (fixed) displacement.
   ID(M,N) = 2; deleted (fixed) displacement, used for generation.

   An unspecified [ID(M,N)=0] degree of freedom is free to translate as the solution dictates. Concentrated forces may be applied in this degree of freedom.

   One system equilibrium equation is required for each unspecified degree of freedom in the model. The maximum number of equilibrium equations is always less than two (2) times the total number of nodes in the system.

   Constrained [ID(M,N)=1] degrees of freedom are deleted from the final set of equilibrium equations. Deleted degrees of freedom are used to define fixities (points of external reaction), and any loads applied in these degrees of freedom are ignored by the program.

   For generation purposes the value ID(M,N) = 2 can also be used. In this case, if the corresponding value on the next input card is zero (0), it is set equal to "2". Considering the deletion of degrees of freedom at two (2) have the same meaning as a plus one (+1).

NODAL POINT DATA

Card 3.1 (Continued)

4. Node cards need not be input in node order sequence; eventually, however, all nodes in the set [1,NUMNP] must be defined. Node data for a series of nodes

$$[N_1, N_1+1*KN_1, N_1+2*KN_1, \ldots, N_2]$$

may be generated from information given on two (2) cards in sequence--

CARD 1 -- N_1,ID(N_1,2),ID(N_1,3),Y(N_1),...,KN_1

CARD 2 -- N_2,ID(N_2,2),ID(N_2,3),Y(N_2),...,KN_2

KN_1 is the node generation parameter given on the first card in the sequence. The first generated node is N_1+1*KN_1; the second generated node is N_1+2*KN_1, etc. Generation continues until node number N_2-KN_1 is established. Note that the node difference N_2-N_1 must be evenly divisible by KN_1.

In the generation the boundary condition codes (ID(L,J) values) of the generated nodes are set equal to those of Node N_1. The coordinate values (Y,Z) are interpolated linearly.

LOAD CONTROL CARDS

Card 4.1

1. NLOAD determines the number of cards to be read as the nodal forces in Card Group 7. The loads defined are concentrated node forces that do not change direction as the structure defoms; i.e., the applied node forces are conservative loads.

2. Time dependent loads are applied to the structure by means of load (or time) function [i.e., f(t)] references and function multipliers assigned with the loads. At time t the value of f(t) is found by linear interpolation in the table of f(t) vs. t; f(t) times the multiplier is the magnitude of the applied load at t. NPTM is the maximum number of [f(t), t] pairs used to describe any one of the NLCUR functions; an individual function may have fewer than NPTM [f(t), t] points as input, but no function can be input with more than NPTM points. At least two points are required per functon; otherwise interpolation in time is not possible.

3. In elastic-plastic analysis with the cap model, plastic loading and then unloading may be encountered. In this case, a switch from the tangent modulus to elastic material matrix is necessary in order to obtain a convergent solution. NTURNS indicates the number of plastic unloading (or reverse loading) for the problem.

LOAD CONTROL CARDS (Continued)

Card 4.2

1. TRV is the list of the time of all the load steps at which the unloading begins, when the current time of the analysis match with the time indicated in TRV list, the elastic stiffness of the elements in the specified group will be used in forming the structure stiffness matrix.

TRUSS ELEMENT (See Fig. V.1)

Card 5.1

1. TRUSS element numbers begin with one (1) and end with the total number of elements in this group, NPAR(2).

2. The parameter NPAR(3) is applicable only if the element group is nonlinear. If NPAR(3).EQ.1, no geometric nonlinearities are taken into account, i.e. the geometric stiffness matrix is not included. If NPAR(3).EQ.2 large displacement effects are included in the analysis, but small strains are assumed in the calculation of element forces.

3. In any one element group only one material model can be used, and this model type is defined by the entry NPAR(15). If NPAR(15).EQ.1 the model is defined by Young's modulus only and NPAR(17).EQ.0. If NPAR(15).EQ.2 the stress-strain curve is defined by input data.

   The model defined for the element group must be consistent with the nonlinear formulation used (defined by NPAR(3)) and the requirement of equilibrium iteration as defined on Card 2.2 of the Master Contrl Cards (Card Group 2). As stated in note (3) of card 2.2, equilibrium iterations can only be performed if the model allows for iteration, and if at least one nonlinear element group is used in the analysis.

4. The variable NPAR(16) defines the number of sets of material/section properties to be read in.

5. For the nonlinear elastic material model (NPAR(15).EQ.2), NPAR(17) is two times the maximum number of points used to describe the nonlinear stress atrain curves.

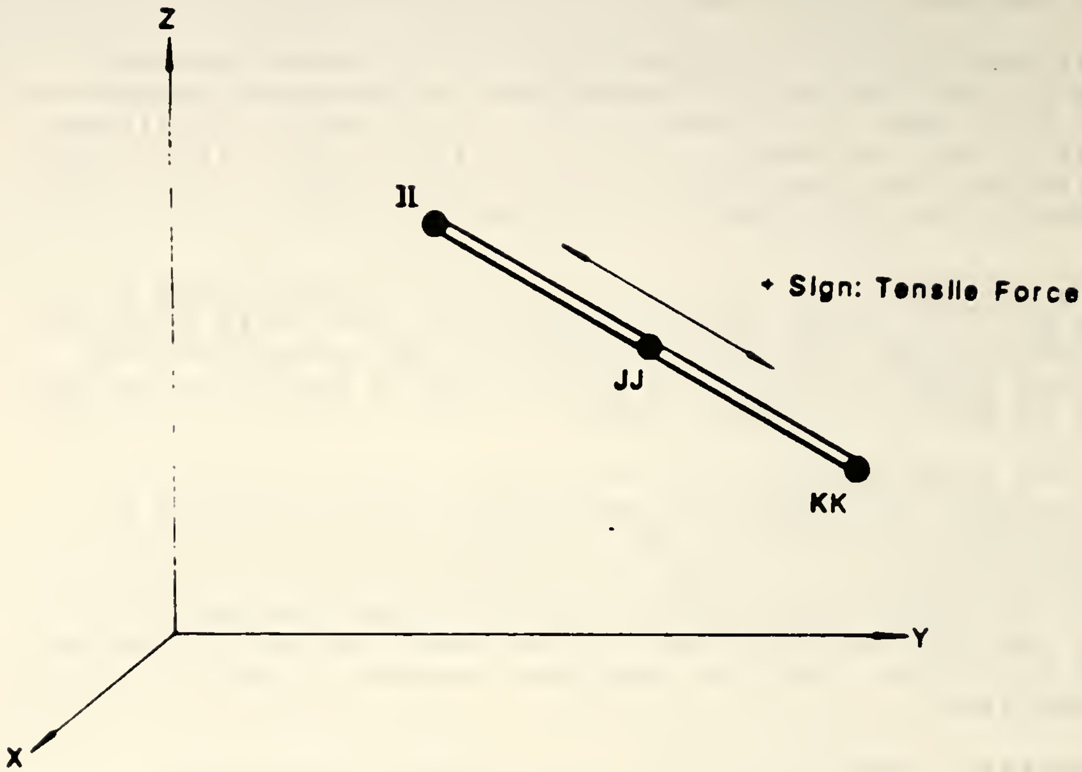


Figure V.1. A truss element.

TRUSS ELEMENT (Continued)

Card 5.2

1. NPAR(16) different linear elastic materials are input in this section, provided NPAR(15).EQ.1. Note that one material/section is defined to have the same Young's modulus, area, and initial axial force.

TRUSS ELEMENT (Continued)

Card 5.3

1. One section property card is defined to have the same area, intial axial force, and time when element is activated.

2. PINIT is an initial axial force.

3. Time element is activated. This option is useful for incremental construction.

4. The stress-strain curve is defined by straight lines between the input points (ε^i, σ^i). From the stress-strain curve total stresses and the tangent modulus are evaluated for a given strain (see Fig. V.2).

   The variable NCON was defined in CARD 5.1 by the variable NPAR(17).

   This model can only be used in a nonlinear element group.

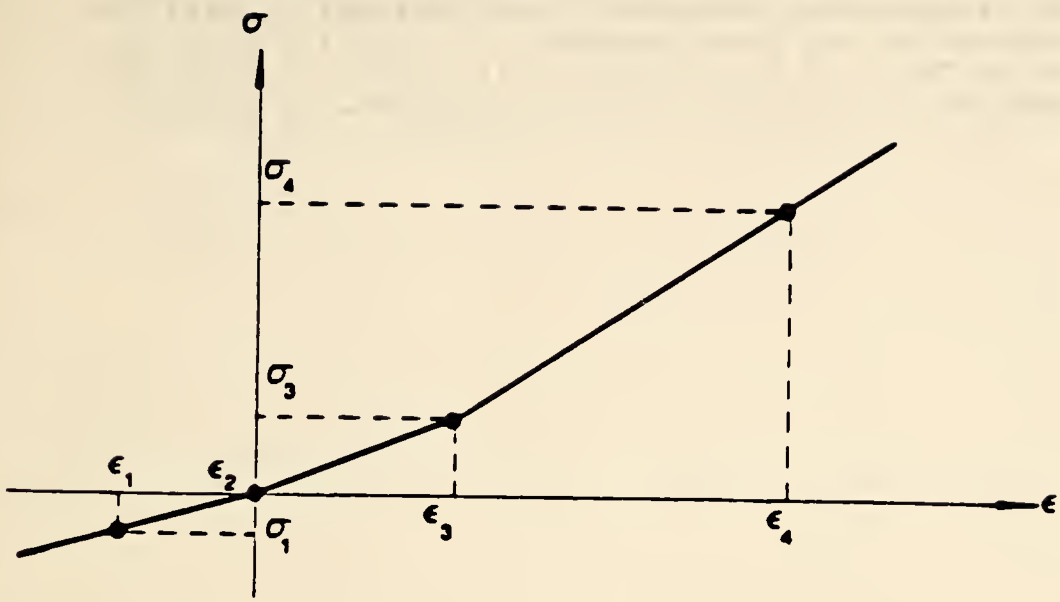


Figure V.2. A nonlinear stress-strain curve for the truss element.

TRUSS ELEMENT

Card 5.6

1. Refer to Figure V.1. For two-node truss members the third node is zero.

2. Elements must be input in increasing element number order. If cards for elements [M+1, M+2,...,M+J] are omitted, these "J" missing elements are generated using MTYP of element "M" and by incrementing the node numbers of successive elements with the value "KG"; KG is taken from the first card of the element generation sequence (i.e., from the "M-th" element card).

2-D CONTINUUM ELEMENTS

2-D CONTINUUM elements are 4- to 8-node isoparametric plane strain quadrilaterals. They must be input in the global Y-Z plane. Each element node has two (2) translational degrees of freedom.

2-D CONTINUUM ELEMENTS

Card 6.1

(1) 2-D CONTINUUM element numbers begin with one (1) and end with total number of elements in this group, NPAR(2). Element data are input in CARD 6.4. For the IBM-PC version NPAR(3)*156 + NPAR(16)*46.LE.15936 to limit the length of unformatted records written to disk. Larger groups may have to be divided into 2 groups.

(2) NPAR(3) is applicable for non-linear groups only and determines if geometrical nonlinearities are to be included in the analysis. If NPAR(3).EQ.1 displacements and strains are assumed to be infinitesimal. In the updated Lagrangian Formulation all geometric effects (large displacements or large strains) are included in the analysis.

(3) NPAR(7) limits the number of nodes that can be used to describe any of the elements in this group. A minimum of 4 and a maximum of 8 nodes are used to describe the 2-D CONTINUUM elements. Although 5 or 7 node elements can be used, to ensure numerical accuracy either 4, 6 or 8 node elements are recommended for use as shown in Fig. VI.1.

(4) For rectangular elements an integration order of "2" is sufficient. If the element is distorted, a higher integration order need be used. Notice that apart from the larger computational effort in the calculation of the element matrices, more working storage is required if a nonlinear material model is used (see note (5) below). Stresses are output at each integration location as shown in Fig. VI.2.

(5) Only one material model (defined by the value of NPAR(15)) is allowed in an element group. PS-NFAP supports only model numbers 1 and 10. If NPAR(15) is "1" the entries for NPAR(17) and NPAR(18) are ignored by the program. If NPAR(15) is "10", material constants are read into the storage array "PROP" which has dimensions NPAR(17) by NPAR(16): i.e., property constants are stored as,

((PROP(I,J), I = 1, NPAR(17)), J = 1, NPAR(16))

Model 10 requires that NPAR(17).EQ.22 and that the dimension of the storage array for element history NPAR(18).EQ.12. The NPAR(18) parameters which characterize element history must be retained for materially

2-D CONTINUUM ELEMENTS

Card 6.1 (Continued)

nonlinear elements so that properties can be chosen in the current solution step. The working storage array (WA) is dimensioned by IDWA*NPAR(2); where:

IDWA = NPAR(18)*(NPAR(10)**2)*NPAR(2)*2

The model defined for the element group must be consistent with the nonlinear formulation used (defined by NPAR(3)), the element type (defined by NPAR(5)), and the requirement of equilibrium iteration as defined on Card 2.2 of the Master Control Cards. As stated in note (3) of Card 2.2, equilibrium iteratons can only be performed if the model allows for iterations, and if at least one nonlinear element group is used in the analysis.

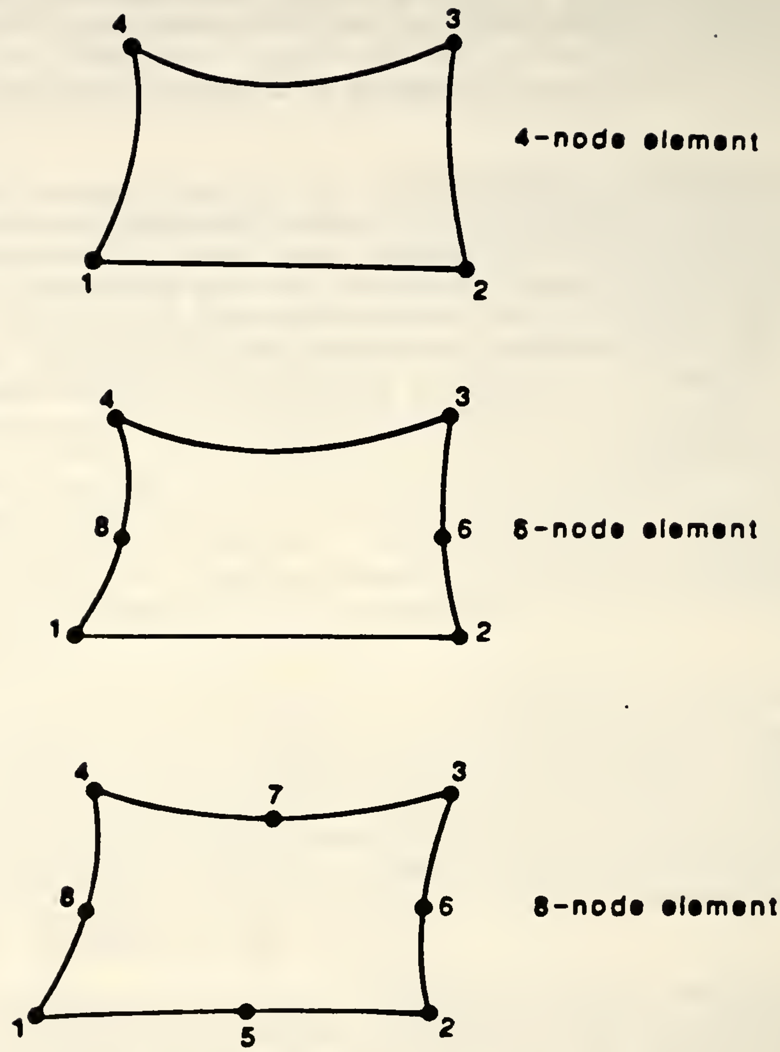
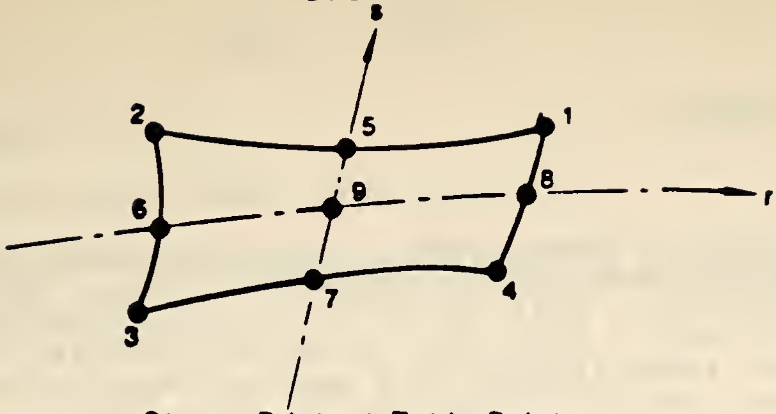
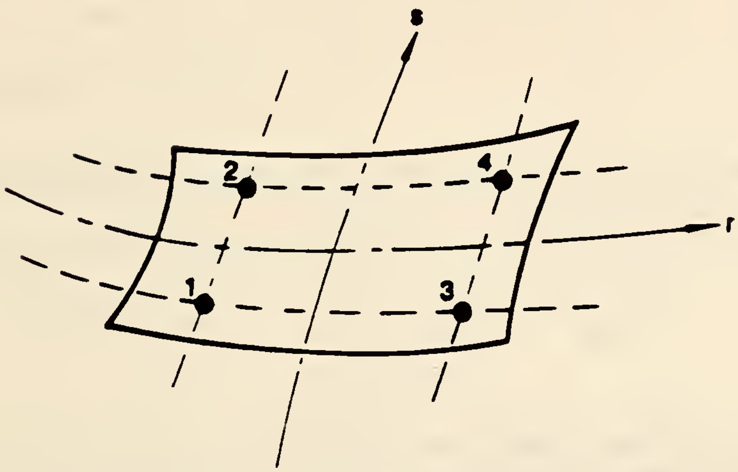


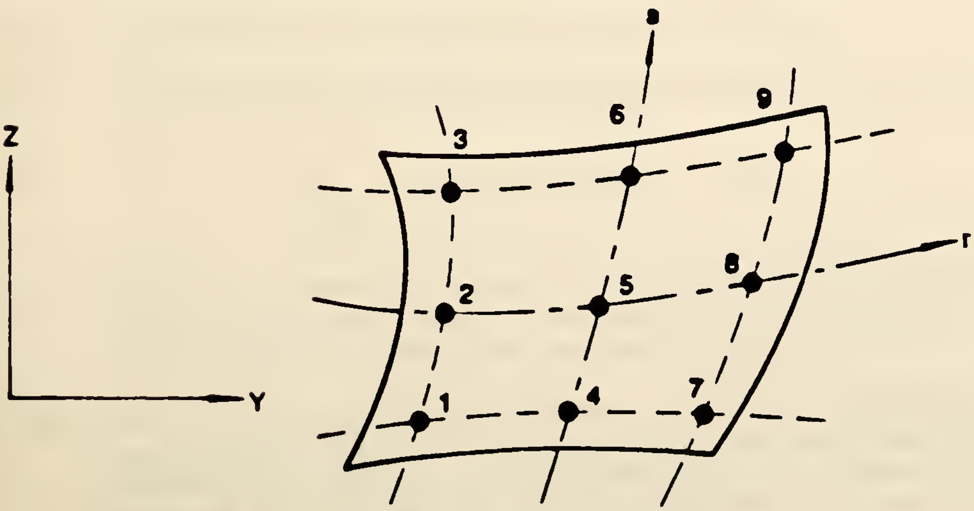
Figure VI.1. Recommended use of 2-D elements.



Stress Printout Table Points
for 2-D Continuum Elements



2-Point Integration



3-Point Integration

Figure VI.2. Stress print-out convention for 2-D continuum elements.

2-D CONTINUUM ELEMENT

Card 6.3.1

(1) MODEL 1 is a linear elastic, isotropic material defined by two (2) positive constants (E,ν); i.e., if NPAR(15).EQ.1, NPAR(17) is set to "2" by default. MODEL 1 can be used with linear or nonlinear element groups. Since the material constants are independent of history, NPAR(18) is set to "0" by default.

-D CONTINUUM ELEMENT

Card 6.3.10 Soil Plasticity Model, NPAR(15) = 10

Model 10 is a capped plasticity model consisting of a work-hardening surface and a perfectly plastic surface. The work-hardening surface has the form:

$$F = (I_1 - XL)^2 + R^2 J_2 - (X - XL)^2 = 0$$

where I_1 is the first stress invarient and J_2 is the second deviatoric stress invarient. The perfectly plastic surface is of the Drucker-Prager type and has the form:

$$AM * I_1 + J_2^{1/2} - AC = 0$$

The cap model is shown in Fig. VI.3.

(1)

The parameters K_1, K_2, A_p, K_{min}, G_1 and G_2 are used to represent the elastic moduli. They have the form:

$$K = MAX\ (K_1 * A_p * [-I_1/(3*A_p)]^{K_2},\ K_{min})$$

$$G = G_1 + G_2 * K$$

where K and G are the bulk and shear moduli, respectively and K_1, K_2, G_1, and G_2 are fitting parameters; K_{min} must be .GE.0.0 and is the minimum value of K; A_p is atmospheric pressure and has the same units as K.

(2) AM and AC are defined in Figure VI.3.

(3) AW and AD are material parameters for the hardening rule.

$$\varepsilon_{kk}^{p} = AW\ [\exp(AD*X) - 1.]$$

(4) R is the aspect ratio of the work-hardening elliptical cap. The aspect ratio is defined as the ratio of the horizontal to vertical axis of the ellipse.

(5) XL is the initial position of the elliptical cap defined by the intersection of the cap and ultimate failures surface. For normally consolidated soil XL should be set equal to +1. and the initial cap position will be calculated by the program.

(6) TENCUT is the maximum principle tension stress. The material is assumed to fracture after reaching this value.

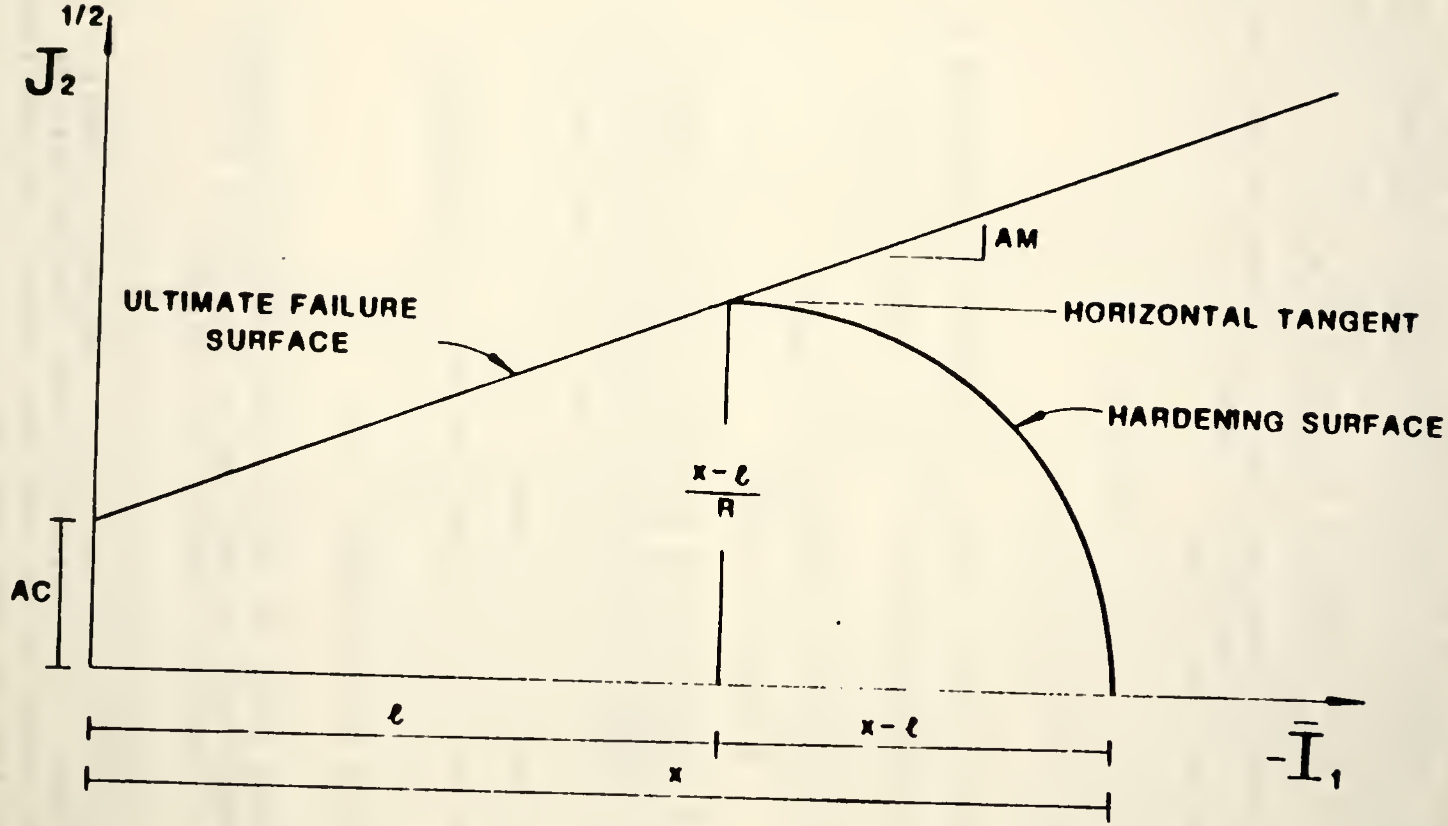


Figure VI.3. Cap model.

2-D CONTINUUM ELEMENT

Card 6.3.10 (continued)

(7) STATE is a material parameter which controls whether the cap is allowed to contract as well as expand along the hydrostatic axis:

STATE = 1 for expansion and contraction.
> 1 for expansion only

(8) A_1, A_2 and K_0 are used to define the initial stresses:

$$\sigma_z = A_1 * Z + A_2$$

$$\sigma_y = K_0 * \sigma_z$$

$$\sigma_x = K_0 * \sigma_z$$

where Z is the Z-coordinate of the Gauss point under consideration. If initial stresses are specified, they must be compensated by balancing nodal loads in Section VII. Initial stresses cannot be specified if incremental construction (PROP(20), PROP(21), and PROP(22)) is used.

(9) SWITCH is the time at which the analysis is switched from drained to undrained conditions. It must correspond to the exact time at which one of the solution time steps occurs. For times less than switch no pore pressures are generated. Set SWITCH.EQ.0.0 if this option is not used.

(10) FAC is used to compute the bulk modulus of water for use in an undrained analysis:

$$K_w = FAC * K$$

where K is the bulk modulus of the soil. The pore pressures are assumed to be 0 for material that has failed in tension so the program sets FAC = 0 for this case.

FAC > 0	computes positive and negative excess pore pressures
FAC = 0	drained conditions; no pore pressures generated
FAC < 0	computes only negative excess pore pressures; sets pore pressure = 0 for material with positive volumetric strain

2-D CONTINUUM ELEMENT

Card 6.3.10 (continued)

(11) TIME-ON is the time at which the elements associated with this set of material parameters becomes active. TIME-ON must correspond to the exact time at which one of the program time steps occurs. For time less than TIME-ON, no element stresses develop. This is used for incremental construction. Incremental construction cannot be used if initial stresses (PROP(15), PROP(16), and PROP(17)) are specified.

(12) WGT and BOUY are used to calculate the gravity and bouyancy forces on an element for which the TIME-ON option is used. Bouyancy forces are calculated if a Gauss point falls below the water table which is assumed to be at Z = 0.0. The weight and bouyancy forces are increased from zero at time "TIME-ON" to the value defined by (WGT-BOUY) at time "TIME-ON" + 1 in the manner

$$BF = XFAC * (WGT-BOUY)$$

$$XFAC = Time-(TIME-ON)$$

$$XFAC = \text{Minimum of } (XFAC, 1.0)$$

Only two cases can be modeled: (1) the water table at the ground surface in which case BOUY is the unit weight of water; or (2) no water table in which case BOUY is zero.

Note: For this Model NPAR(17).EQ.22 and NPAR(18).EQ.12

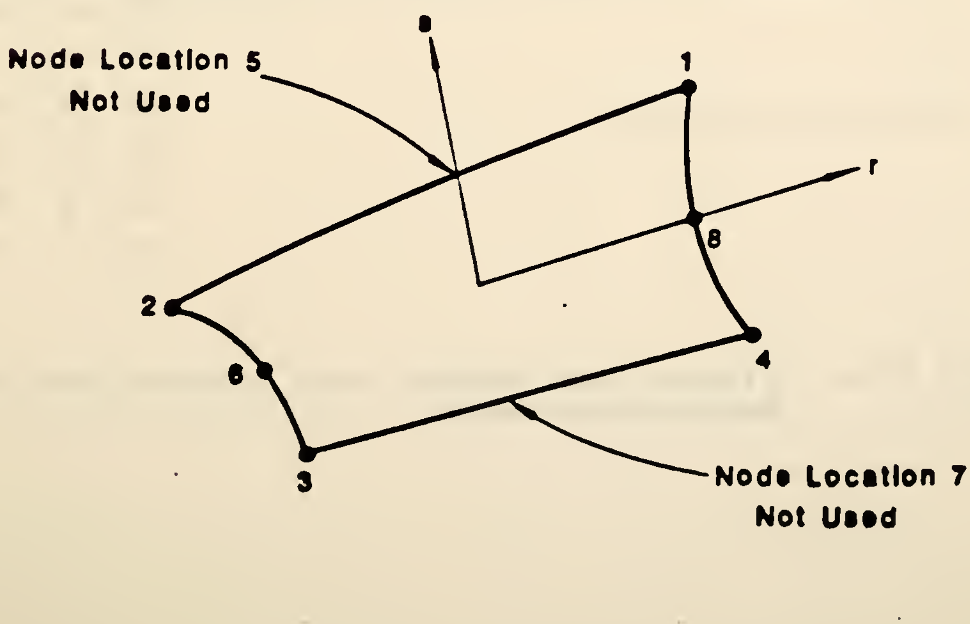
2-D CONTINUUM ELEMENT (Continued)

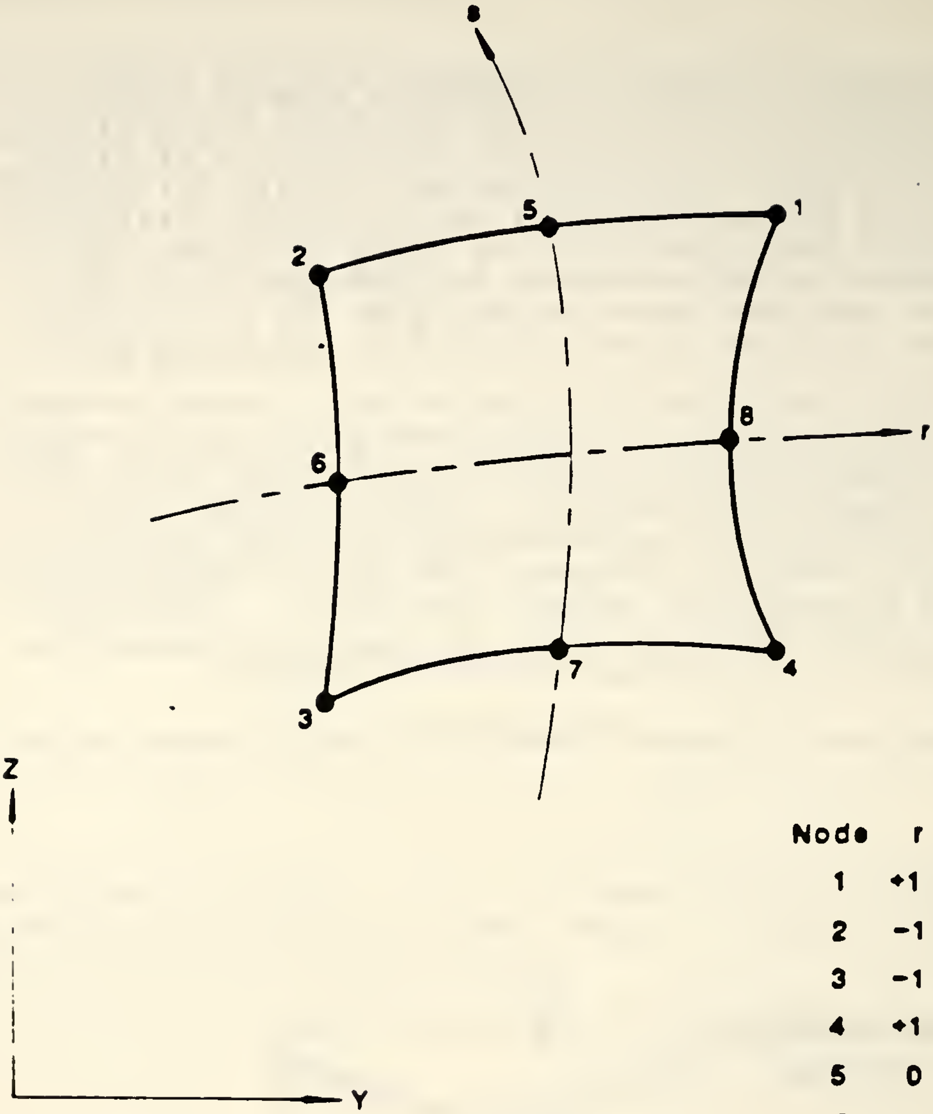
Card 6.4

(1) Elements must be input in ascending element number order. If data cards for elements [M+1, M+2, ..., M+J] are omitted, these "J" missing elements are generated using IEL, IPS, and MTYP given on the card for element "M" and by incrementing node numbers of successive elements with the value "KG"; the value of KG used for incrementation is taken from M-th element card, and only the non-zero nodes appearing on the M-th element card are incremented when generating missing element data.

(2) The number of nodes in element "M" is defined by "IEL". However, all 8 entries for NOD(I) are read from the element data card; if IEL.LT.8 the particular node locations not used in this element need be input as "0" in NOD(I). Fig. VI.4 defines the input sequence that must be observed for element node input. Triangular elements are formed by using the same node number for locations 1, 2 and 5 as shown in Fig. VI.5.

An example of a 6-node element (IEL.EQ.6) shown below:





Node	r	s
1	+1	+1
2	−1	+1
3	−1	−1
4	+1	−1
5	0	+1
6	−1	0
7	0	−1
8	+1	0

Figure VI.4. Element node number input sequence for 2-D continuum elements.

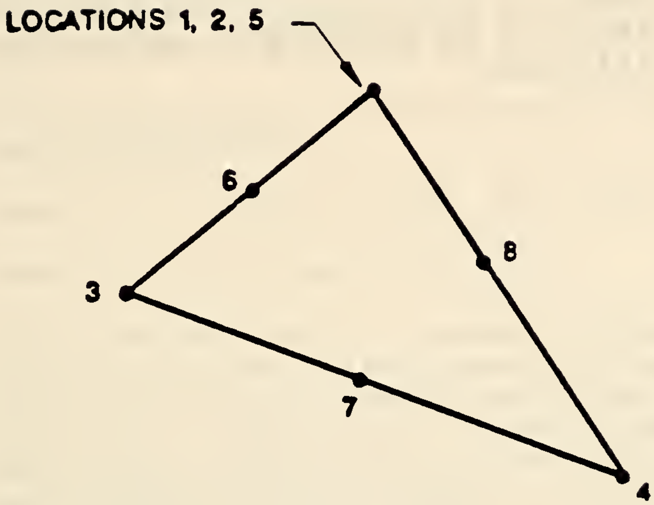


Figure VI.5. Element node numbering for triangular elements.

APPLIED LOADS DATA

Card 7.1b

(1) Time values at successive points must increase in magnitude (i.e., TIMV(1) < TIMV(2) < TIMV(3), etc.). The last time value must be greater than or equal to the time at the end of solution; i.e. TIMV(NPTS) > TSTART + NSTE*DT

(2) Input as many cards in this section as are required to define NPTS points, four points per card.

APPLIED LOADS DATA

Card 7.2

(1) If the same degree of freedom (IDIRN) at the same node (NOD) is given a multiple number of times, the program adds the loads algebraically.

(2) Nodal loads data which are applied as a series of nodes

N_1, N_1 + 1* KN, N_1 + 2*KN . . . . . ., N_2

may be generated from information given as 2 cards in sequence.

Card 1 /N_1, IDIRN, NCUR, FAC, KN /

Card 2 /N_2, IDIRN, NCUR, FAC/

KN is the generation parameter given on the first card. The first generated loaded node is N_1 + 1*KN; the second generated loaded node is N_1 + 2*KN, etc. Generation continues until node number N_2-KN is established. The node difference N_2-K_1 must be evenly divisible by KN.

The series of generaed nodes will have the same IDRIN, NCUR, and FAC.

[illegible]

APPENDIX E

EXAMPLE
ANALYSIS OF REINFORCED EMBANKMENT
ON SOFT GROUND

INTRODUCTION

This appendix illustrates the use of the computer programs described in this manual and procedures used to analyze reinforced embankments constructed on soft foundations. Example input and output files for programs CPCALC, CAP, AUTOGEN, and PS-NFAP along with its auxiliary program NFMINX are given. Appendices A through D should be consulted for detailed explanation of the individual records shown in the example input files. A detailed description of the procedures to determine the cap parameters is given in Humphrey and Holtz (1986); only parameters that are directly related to program operation are discussed here.

PROBLEM DEFINITION

The problem chosen for this example is a granular embankment with a 90-foot base width and 2h:1v side slopes. The foundation is composed of a 7.5-foot thick overconsolidated dried crust underlain by 22.5 feet of soft normally consolidated clay as shown in Fig. E.1. The water table is at the ground surface. The embankment was constructed in horizontal lifts and there was no time for excess pore water pressures in the foundation to dissipate. The fill has a unit weight of 125 psf, Mohr-Coulomb friction angle of 32°, and negligible cohesion. Elastic parameters were based on nonlinear stress strain parameters given by Rowe, et al. (1984). A Poisson's ratio of 0.33 was used. Properties for the normally consolidated foundation soils are given in Table E.1. The strength parameters were obtained from K_o consolidated undrained triaxial compression tests. The the surface crust has the same properties except that the undrained shear strength (s_u) is 125 psf and K_o is 0.6. The embankment is reinforced by a single layer of tensile reinforcement placed on the ground surface as shown in Fig. E.1. The reinforcement has a modulus of 60 k/ft (5000 lb/in.) which is representative of a strong geotextile or geogrid.

CAP PARAMETERS FOR FOUNDATION

Behavior of the foundation soil was represented with the cap model. To determine α from φ' and $J_{2f}^{1/2}/\sigma'_{vo}$ from s_u it is necessary to assume a value of n_f which is a function of the intermediate principal stress at failure (Humphrey and Holtz, 1986) where n_f is defined as

$$n_f = (\sigma_2 - \sigma_1)_f \,/\, (\sigma_3 - \sigma_1)_f$$

where: σ_1 = major principal stress

σ_2 = intermediate principal stress

σ_3 = minor principal stress

The assumed η_f is compared to the average value at failure in the foundation as computed by PS-NFAP. The resulting α = 0.183 and $J_{2f}^{1/2}/\sigma'_{vo}$ = 0.339.

The cap parameters were determined with the aid of the program CPCALC. The program calculated Dx_o, $W/(a-b)$, and R as well as x_f/x_o, R_{max}, and $(x_f/x_o)_{max}$. Program input and output is shown in Fig. E.2 and the variables are defined in Appendix A.

The remaining cap parameters were determined using the procedures given in Humphrey and Holtz (1986) and the guidelines given in Appendix D. The parameters for the normally consolidated and overconsolidated soils are summarized in Table E.2. The value of D is a function of x_o which can be computed once the FE mesh is selected. Note that a minimum value of the bulk modulus (K_{min}) of 1.0 ksf was assumed. This small value avoids numerical difficulties at low stress levels. A small cohesion (κ) is also used to avoid numerical difficulties. The water table is at the ground surface so γ is the buoyant unit weight. The initial stresses are specified so balancing nodal loads must be applied as discussed in a later section. The options to switch from drained to undrained analysis and for incremental construction are not used so SWITCH, TIMEON, WGT, and BOUY = 0.0.

The undrained stress strain behavior predicted using the cap parameters in Table E.2 was checked with the program CAP for a normally consolidated sample with an initial vertical stress equivalent to a depth of 10 feet (A_2 = σ'_{vo} = 0.526 ksf) and a K_o of 0.47. The input file is shown in Fig. E.3. Appendix B should be consulted for a description of the input records. The output file is listed in Appendix E.1 along with 2 files containing stress strain data for input into commercial plotting programs. The calculated $J_2^{1/2}/\sigma'_{vo}$ and normalized pore pressure versus axial strain is plotted in Fig. E.4. The calculated $J_{2f}^{1/2}/\sigma'_{vo}$ was 0.340 which is within 0.3% of the value used to calibrate the model. These should be compared to observed laboratory test results and the model parameters adjusted if necessary to obtain a better fit.

PARAMETERS FOR EMBANKMENT FILL

The embankment fill was modeled using only the Drucker-Prager ultimate failure surface (Humphrey and Holtz, 1986). This is done by fixing the initial position of the cap (XL) well beyond the maximum stress level that occurs in the problem. An XL of -1.0×10^{10} ksf was chosen and STATE = 2.0 prevents contraction of the cap. The remaining parameters directly associated with the cap (AW, AD, and R) are not used and are assigned a value of 1.0. Other parameters were determined from the soil properties given above using the

procedures given in Humphrey and Holtz (1986) and from the guidelines given in Appendix D. All the parameters are summarized in Table E.3. Small values of K_{min} and κ are assumed to avoid numerical difficulties. Incremental construction was used so WGT and BOUY are specified. Selection of TIMEON is discussed in the following section.

SELECTION OF FINITE ELEMENT MESH

The problem geometry was modeled by the finite element mesh shown in Fig. E.5. The geometry is symmetric about the embankment centerline so only half the problem needs to be represented by the FE mesh. The ground surface should be chosen as Z = 0.0. Two nonlinear element groups were used so (NEGNL = 2 on PS-NFAP card 2.1; see Appendix D.1). One modeled the foundation and embankment fill using 52 nonlinear 2-D elements and the other modeled the reinforcement using 3 nonlinear TRUSS elements. There are no linear element groups (NEGL = 0 on PS-NFAP card 2.1).

The foundation was divided into 4 layers of 8 node nonlinear 2-D elements with dimensions 7.5 feet high by 15 feet long. The top layer represents the dried surface crust and the bottom 3 layers represents the normally consolidated soils. The value of x_o can now be computed using the procedures given in Humphrey and Holtz (1986) and then used to determine the cap parameter D in each layer.

The embankment was constructed in horizontal lifts. This was simulated in the FE analysis with an incremental procedure. Each lift is represented by a row of elements. During each time step in the analysis the stresses in the next row of elements are increased from zero to their full value in one or more sub-increments. Elements above the current lift are inactive and are said to be "ghost elements". The cap parameter TIMEON specifies the time when an element is activated. For example the stresses in the first lift are increased from zero at time = 0.0 to their full value at time = 1.0 so the elements have TIMEON = 0.0 ≈ 0.01 (note that a value slightly greater than zero should be specified for the first lift to prevent it from being included in the initial conditions which are established at time = 0.0), for the second lift TIMEON = 1.0 and the stresses are fully applied at time = 2.0, for the third lift TIMEON = 2.0, etc. A lift thickness of 1.875 feet was used and the load was increased to its full value in 2 sub-increments (DTPER = 0.5 on PS-NFAP card 2.3). Although the thickness is larger than typical construction lifts, thinner lifts would require either unacceptably thin elements or an excessive number of elements. It was estimated that the embankment would fail at a height of less than 11.25 feet so 6 lifts were used. A combination of 8 node rectangular, trapezoidal and triangular nonlinear 2-D elements were used as shown on Fig. E.5.

The reinforcement was modeled with three three-node nonlinear TRUSS elements located at the interface between the fill and foundation soils as shown on Fig. E.5. To simulate a material that can support only tensile forces the stress strain curve shown in Fig. E.6 was used. Stress is expressed as the force times cross-sectional area. To be consistent the cross-sectional area of the elements is 1.0 sq.ft. (AREA = 1.0 on PS-NFAP card 5.3a). Note that the curve does not pass exactly through the origin since this can result in numerical difficulties under some circumstances. The reinforcement is in place at the start of construction so TIMEON = 0.0 (TIMEON = 0.0 on PS-NFAP card 5.3a).

USE AUTOGEN TO CREATE PS-NFAP INPUT FILE

AUTOGEN was used to create the PS-NFAP input file. The input and output files are shown in Appendices E.2 and E.3 respectively. Comments explaining how the AUTOGEN commands were used are included on the input file. Appendix C should be consulted for a detailed description of the commands and PS-NFAP input records are described in Appendix D. The output file will be used as the PS-NFAP input file.

The LOAD command was used to generate nodal loads to balance the initial vertical stress specified in the foundation soil by the cap parameters. A vertical load is generated for each of the 136 nodes in the foundation (therefore NLOAD = 136 on PS-NFAP card 4.1). These loads correspond to load curve 1 (PS-NFAP cards 7.1a and 7.1b) as shown in the AUTOGEN input file.

Load curves 2 through 7 are optional and serve only as a reminder of the load applied in each construction lift. For example, curve 2 corresponds to the first lift and shows that the load is zero at time = 0.0 and is -1.0 (the minus sign indicates that the force is applied downward) for time $\geq$ 1.0. The last card group in the AUTOGEN input file is the FOLL command.

USE NFMINX TO RENUMBER NODES

The auxillary program NFMINX was used to renumber the nodes to minimize the bandwidth of the stiffness matrix. This separate step is only necessary in the IBM-PC version; it is done directly by PS-NFAP in the mainframe version. The input file is the PS-NFAP input file shown in Appendix E.3. NFMINX generates a list of the renumbered nodes shown in Appendix E.4 and a file named 'NFMIN.NFP' which will be used by PS-NFAP.

EXAMPLE RUN WITH PS-NFAP

The problem is now ready for analysis with PS-NFAP. The solution was carried out up to time = 1.0 during which the first lift was placed. The input file is shown in Appendix E.3 and the output file is shown in Appendix E.5. At the end of program execution the files TAPE8 and TAPE9 are saved on disk for future use by a restart job that would resume the analysis at time = 1.0. If the analysis had been continued it would show that the solution does not converge at time = 5.5 so 5 lifts can be placed prior to embankment failure.

The problem was run on an IBM-PC with with a math co-processor chip, 640K of memory, and a hard disk. The size of the A-matrix in PS-NFAP was set at 72010. The program used the out of core solution option and the execution time was about 20 minutes.

Comments were added to the output shown in Appendix E.5 to assist in its interpretation. In addition, the following should be kept in mind:

1. The coordinate system is Y-direction horizontal (positive to right), Z-direction vertical (negative is down) , and X-direction parallel to the longitudinal axis.

2. Compressive stresses and strains are negative. This is opposite to the convention used in soil mechanics.

3. Stresses are output as effective stresses.

Equilibrium Iteration Output

PS-NFAP outputs equilibrium iteration information for each time step (see Appendix E.5). The variables are defined as follows:

LOAD VECTOR NORM = $[\Sigma(\text{externally applied nodal loads})^2]^{1/2}$

INCREMENTAL LOAD NORM= $[\Sigma(\text{loads added during time step})^2]^{1/2}$

MAX INCREMENTAL LOAD = Maximum of all incremental loads added at the nodes

SUM GENERATED GRAV LOAD = Sum of total load applied using incremental construction

UNBALANCED NORM = measure of unbalanced forces
= $[\Sigma(\text{applied load - resisting forces})^2]^{1/2}$

MAX UNBALANCED -- DOF = maximum unbalanced force
= MAX(applied load - resisting force) and the DOF or equation number at which it occurs

IDNORM = Incremental displacement norm
$= [\Sigma(\text{incremental displacements})^2]^{1/2}$

DNORM = Displacement norm
$= [\Sigma(\text{nodal displacements})^2]^{1/2}$

GTOT = Sum of total load applied using incremental construction minus buoyancy forces

If the solution is converging properly the UNBALANCED NORM, magnitude of the MAX UNBALANCED force, and IDNORM should decrease in each successive iteration and DNORM should approach a constant value.

Stress Output for 2-D Elements

Stresses are output at the iteration points as shown in Appendix D, Fig. VI.2. The variables in the STRESS CALCULATIONS FOR ELEMENT GROUP 1 (2/D CONTINUUM) are as follows:

NUM = Element number

IPT = Iteration point number

STRESS STATE = State of stress; on cap, elastic, etc.

STRESS-XX = σ'_{xx} = Effective normal stress in X-direction

STRESS-YY = σ'_{yy} = Effective normal stress in Y-direction

STRESS-ZZ = σ'_{zz} = Effective normal stress in Z-direction

STRESS-YZ = $\sigma'_{yz} = \sigma'_{zy}$ = Shear stress on Y plane in Z-direction

PORE P = Excess pore water pressure

MAX STRESS = σ'_1 = Major effective principal stress

MIN STRESS = σ'_3 = Minor effective principal stress

ANGLE = Orientation of principal axes relative to Y and Z axes in degrees; counterclockwise is positive

ETA = $\eta = (\sigma_2 - \sigma_1) / (\sigma_3 - \sigma_1)$

CAP POSITION = x = intersection of cap with I'_1 axis

Stress output for TRUSS elements

The force in the reinforcement is output at 3 integration points (IP) in each element. For a straight TRUSS element of length L with its center node at L/2, IP 1 is located at 0.29L, IP 2 is at L/2, and IP 3 is at 0.71L.

REFERENCES

1. Humphrey, D. N., and Holtz, R. D. (1986), "Design of reinforced embankments," Joint Highway Research Project Report, School of Civil Engineering, Purdue University, West Lafayette, IN 47907.

2. Rowe, K. R., MacLean, M. D., and Soderman, K. L. (1984), "Analysis of a geotextile-reinforced embankment constructed on peat," Canadian Geotechnical Journal, Vol. 21, No. 3, August, pp. 563-576.

Table E.1
Normally consolidated soil properties

ϕ'	= 28°
c'	= 0.0
s_u/σ'_{vo}	= 0.32
C_c	= 0.25
C_r	= 0.04
e_o	= 0.7
ν'	= 0.3
K_o	= 0.47
γ_{sat}	= 115 pcf

Table E.2
Cap parameters for normally consolidated and overconsolidated foundation soil

Property number*	Parameter name	Normally consolidated	Over-consolidated
1	K_1	98.0	98.0
2	K_2	1.0	1.0
3	A_p	2.116 ksf	2.116 ksf
4	K_{min}	1.0 ksf	1.0 ksf
5	G_1	0.0	0.0
6	G_2	0.46	0.46
7	AM (α)	0.183	0.172
8	AC (κ)	0.0001 ksf	0.0001 ksf
9	AW (W)	0.146	0.146
10	AD (D)	$-0.996/x_o$	1.19
11	R	0.747	0.747
12	XL (ℓ_o)	+1.0	-0.74
13	TENCUT	0.1 ksf	0.1 ksf
14	STATE	1.0	2.0
15	A_1 (γ)	0.053 kcf	0.053 kcf
16	A_2	0.0	0.0
17	K_o	0.47	0.6
18	SWITCH	0.0	0.0
19	FAC (B)	10.0	10.0
20	TIMEON	0.0	0.0
21	WGT	0.0	0.0
22	BOUY	0.0	0.0

* Corresponds to property number used in Appendix D

Table E.3
Parameters for embankment fill

Property number*	Parameter name	Value
1	K_1	190.0
2	K_2	0.65
3	A_p	2.116 ksf
4	K_{min}	20.0 ksf
5	G_1	0.0
6	G_2	0.33
7	AM (α)	0.17
8	AC (κ)	0.0001 ksf
9	AW (W)	1.0
10	AD (D)	1.0
11	R	1.0
12	XL (ℓ_o)	-1.0×10^{10} ksf
13	TENCUT	0.1 ksf
14	STATE	2.0
15	A_1 (γ)	0.0
16	A_2	0.0
17	K_o	0.0
18	SWITCH	0.0
19	FAC (β)	0.0
20	TIMEON	**
21	WGT	0.125 kcf
22	BOUY	0.0624 kcf

* Corresponds to property number used in Appendix D

**See section on selection of FE mesh

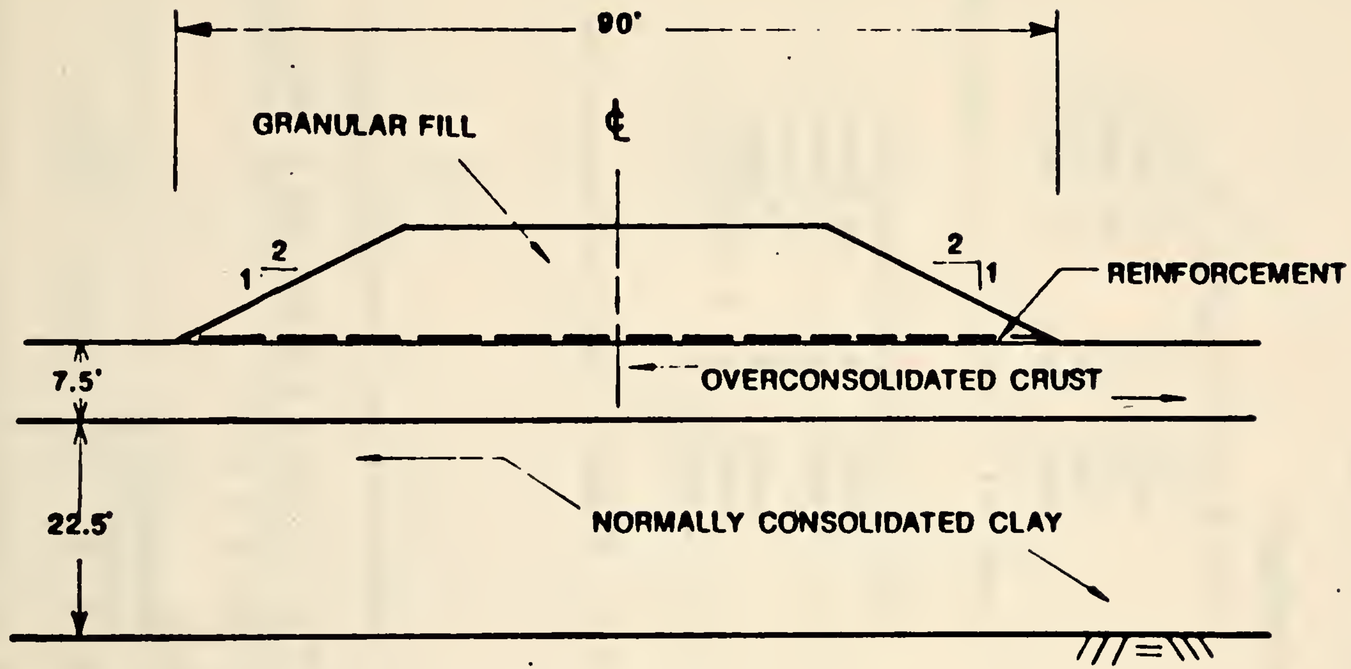


Figure E.1. Example embankment geometry.

Program input:

```
Input-  am,acn,sJ2fn,rkc,abb  -then hit return
Remember that acn and sJ2fn are negative
 0.183 0.0 -0.339 0.47 5.26
```

Program output:

```
          INPUT TEST PARAMETERS:
                am      =       0.18300
                acn     =       0.00000
                sJ2fn   =      -0.33900
                rkc     =       0.47000
                abb     =       5.26000

     *** note  *** slope = 0 error when computing max(xf/xo)


          CALCULATED CAP PARAMETERS:
                dxo     =      -0.99562
                wab     =       2.71830
                r       =       0.74691
                xfxo    =       1.00882
                rmax    =   0.15857E+06
                xfxomx  =       1.10786
```

Figure E.2. Example input and output for program CPCALC.

```
EXAMPLE EMBANKMENT-CAP PARAMETERS NORMALLY CONSOLIDATED CLAY
0 4
98.0 1.0 2.116 1.0 0.0 0.46 .183 0.0001
0.146 0.907 0.747 +1.0 0.1 1.0 0.0 -0.526 0.47
0.0 10.0 0.0 0.0 0.0
stress
0.005 20 0
0 60 0. -0.0005 0. 0.
0 39 0. -0.0002 0. 0.
0 0 0. 0. 0. 0.
```

Figure E.3. Example input for program CAP.

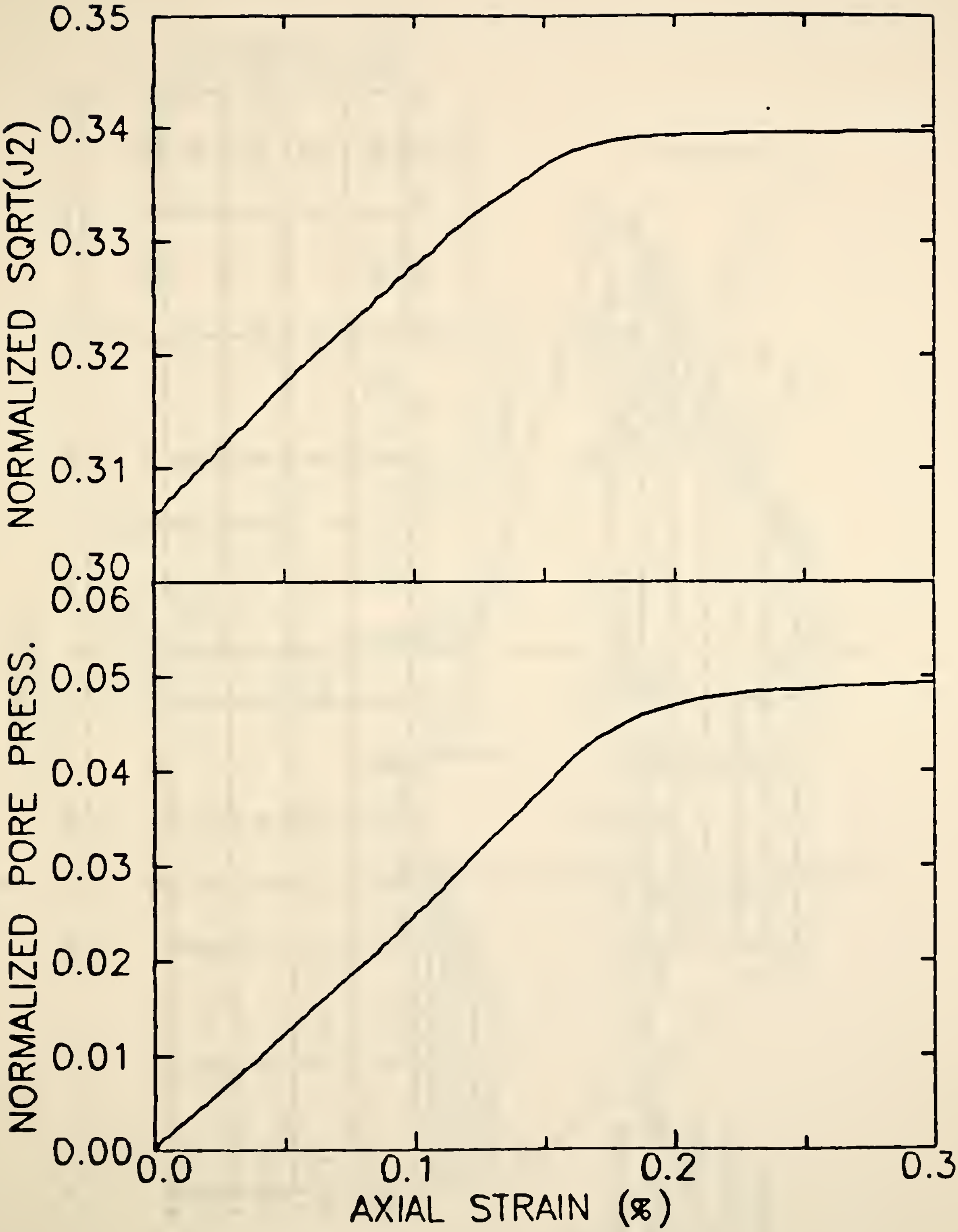


Figure E.4. $J_2^{1/2}/\sigma'_{vo}$ and $\Delta u/\sigma'_{vo}$ vs. axial strain calculated by program CAP for normally consolidated soil.

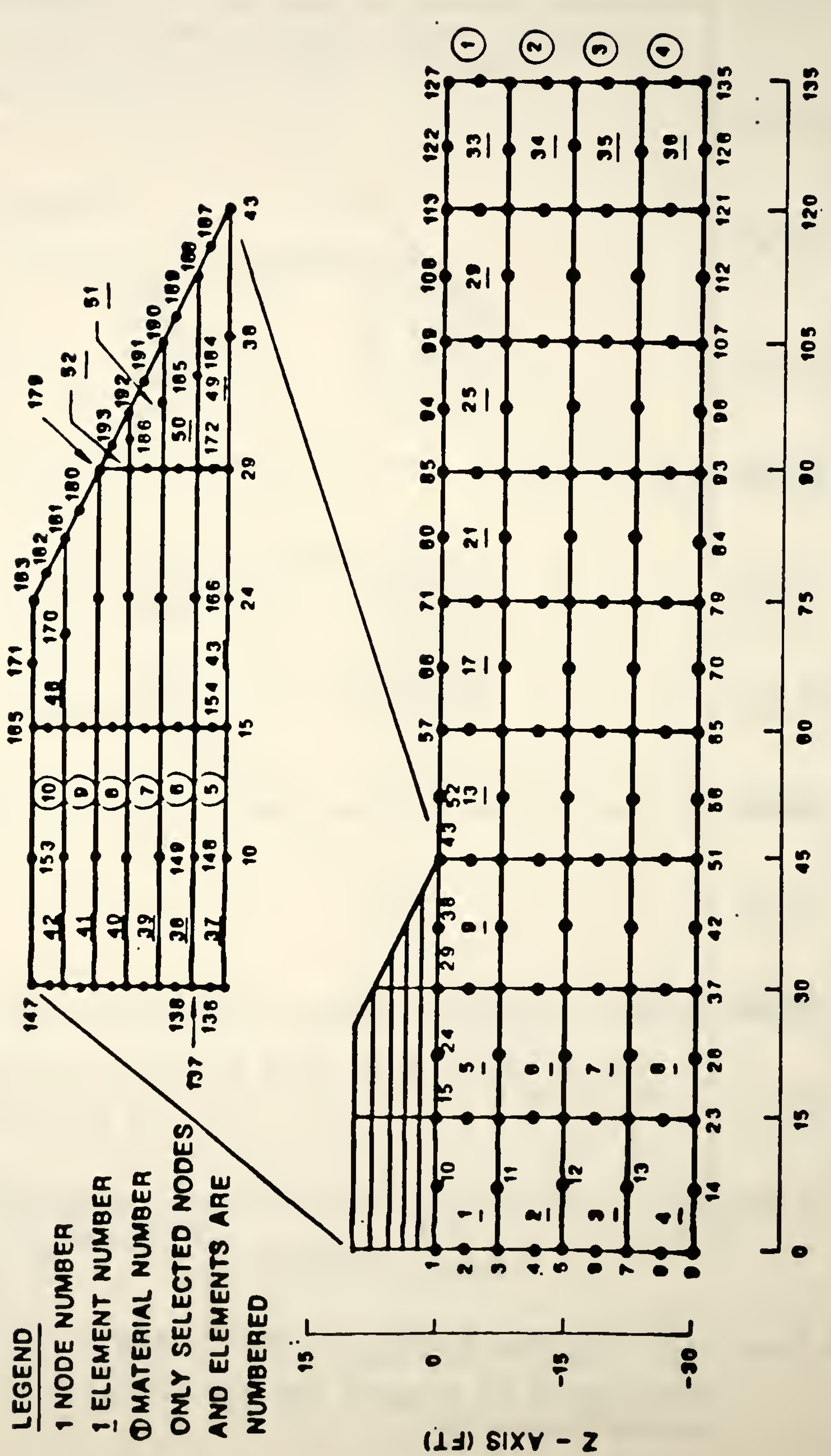


Figure E.5. Finite element mesh for example embankment.

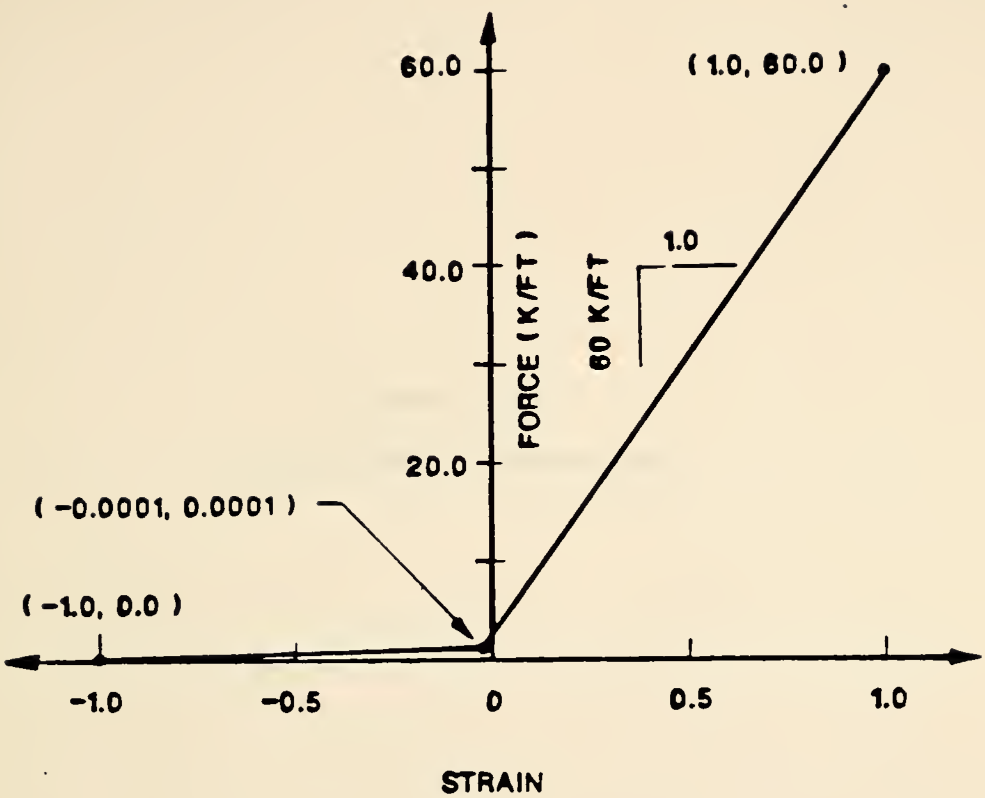


Figure E.6 Stress-strain curve for tensile reinforcement.

APPENDIX E.1

OUTPUT FROM PROGRAM CAP

OUTPUT FROM CAP

```
EXAMPLE EMBANKMENT - CAP PARAMETERS NORMALLY CONSOLIDATED CLAY

CONTROL PARAMETERS

     lcount =          3
     ncon   =         22
     ldv    =         11
     ltyp2d =          0
     ladnl  =          4
     kprl   =          1

CAP PARAMETERS

     prop(1)  = ak1      =     98.00000000
     prop(2)  = ak2      =      1.00000000
     prop(3)  = ap       =      2.11599994
     prop(4)  = akmln    =      1.00000000
     prop(5)  = ag1      =  0.00000000E-01
     prop(6)  = ag2      =      0.46000001
     prop(7)  = am       =      0.18300000
     prop(8)  = ac       =  9.99999975E-05
     prop(9)  = aw       =      0.14600000
     prop(10) = ad       =      0.90700001
     prop(11) = rfl      =      0.74699998
     prop(12) = el       =      1.00000000
     prop(13) = tcut     =      0.10000000
     prop(14) = state    =      1.00000000
     prop(15) = a1       =  0.00000000E-01
     prop(16) = a2       =     -0.52600002
     prop(17) = ko       =      0.47000000
     prop(18) = not used =  0.00000000E-01
     prop(19) = fac      =     10.00000000
     prop(20) = timon    =  0.00000000E-01
     prop(21) = wgt      =  0.00000000E-01
     prop(22) = bouy     =  0.00000000E-01


INITIALIZING MATERIAL PARAMETERS

     INITIAL STRESSES
              syy         szz         syz         sxx
         -0.2472E+00 -0.5260E+00  0.0000E+00 -0.2472E+00

     INITIAL STRAINS
              eyy         ezz         eyz         exx
          0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00

     INITIAL CAP POSITION (el) =     -0.96573702
```

OUTPUT FROM CAP (CONTINUED)

BEGINNING SOLUTION

STRESS PATH SPECIFIED

```
rtol  =  4.99999989E-03
ltmax =          20
lref  =           0
```

nstep	eyy	ezz	eyz	exx	pp	syy	szz	syz	sxx	el	lpel
0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	-0.2472E+00	-0.5260E+00	0.0000E+00	-0.2472E+00	-0.9657E+00	1

LOAD STEP INFORMATION

```
kswtch =          0
ntimes =         60
dsig   =  0.00000000E-01  -5.00000024E-04  0.00000000E-01  0.00000000E-01
```

1	0.5283E-05	-0.1102E-04	0.0000E+00	0.5283E-05	-0.1515E-03	-0.2472E+00	-0.5260E+00	0.0000E+00	-0.2472E+00	-0.9658E+00	3
2	0.1598E-04	-0.3355E-04	0.0000E+00	0.1598E-04	-0.5326E-03	-0.2470E+00	-0.5262E+00	0.0000E+00	-0.2470E+00	-0.9658E+00	3
3	0.2874E-04	-0.5992E-04	0.0000E+00	0.2874E-04	-0.8165E-03	-0.2466E+00	-0.5265E+00	0.0000E+00	-0.2466E+00	-0.9659E+00	3
4	0.3866E-04	-0.8068E-04	0.0000E+00	0.3866E-04	-0.1119E-02	-0.2464E+00	-0.5266E+00	0.0000E+00	-0.2464E+00	-0.9660E+00	3
5	0.5093E-04	-0.1061E-03	0.0000E+00	0.5093E-04	-0.1403E-02	-0.2460E+00	-0.5269E+00	0.0000E+00	-0.2460E+00	-0.9661E+00	3
6	0.6090E-04	-0.1269E-03	0.0000E+00	0.6090E-04	-0.1707E-02	-0.2458E+00	-0.5270E+00	0.0000E+00	-0.2458E+00	-0.9662E+00	3
7	0.7334E-04	-0.1527E-03	0.0000E+00	0.7334E-04	-0.1993E-02	-0.2454E+00	-0.5273E+00	0.0000E+00	-0.2454E+00	-0.9663E+00	3
8	0.8356E-04	-0.1740E-03	0.0000E+00	0.8355E-04	-0.2299E-02	-0.2452E+00	-0.5274E+00	0.0000E+00	-0.2452E+00	-0.9663E+00	3
9	0.9625E-04	-0.2003E-03	0.0000E+00	0.9625E-04	-0.2587E-02	-0.2448E+00	-0.5277E+00	0.0000E+00	-0.2448E+00	-0.9664E+00	3
10	0.1068E-03	-0.2222E-03	0.0000E+00	0.1068E-03	-0.2896E-02	-0.2446E+00	-0.5278E+00	0.0000E+00	-0.2446E+00	-0.9665E+00	3
11	0.1198E-03	-0.2491E-03	0.0000E+00	0.1198E-03	-0.3186E-02	-0.2442E+00	-0.5281E+00	0.0000E+00	-0.2442E+00	-0.9666E+00	3
12	0.1306E-03	-0.2717E-03	0.0000E+00	0.1306E-03	-0.3499E-02	-0.2440E+00	-0.5282E+00	0.0000E+00	-0.2440E+00	-0.9667E+00	3
13	0.1439E-03	-0.2993E-03	0.0000E+00	0.1439E-03	-0.3792E-02	-0.2436E+00	-0.5285E+00	0.0000E+00	-0.2436E+00	-0.9668E+00	3
14	0.1551E-03	-0.3225E-03	0.0000E+00	0.1551E-03	-0.4107E-02	-0.2433E+00	-0.5287E+00	0.0000E+00	-0.2433E+00	-0.9669E+00	3
15	0.1656E-03	-0.3445E-03	0.0000E+00	0.1656E-03	-0.4419E-02	-0.2431E+00	-0.5288E+00	0.0000E+00	-0.2431E+00	-0.9670E+00	3
16	0.1790E-03	-0.3722E-03	0.0000E+00	0.1790E-03	-0.4714E-02	-0.2427E+00	-0.5290E+00	0.0000E+00	-0.2427E+00	-0.9671E+00	3
17	0.1905E-03	-0.3962E-03	0.0000E+00	0.1905E-03	-0.5034E-02	-0.2424E+00	-0.5292E+00	0.0000E+00	-0.2424E+00	-0.9672E+00	3
18	0.2014E-03	-0.4190E-03	0.0000E+00	0.2014E-03	-0.5350E-02	-0.2421E+00	-0.5294E+00	0.0000E+00	-0.2421E+00	-0.9673E+00	3
19	0.2123E-03	-0.4417E-03	0.0000E+00	0.2123E-03	-0.5666E-02	-0.2417E+00	-0.5296E+00	0.0000E+00	-0.2417E+00	-0.9674E+00	3
20	0.2232E-03	-0.4645E-03	0.0000E+00	0.2232E-03	-0.5982E-02	-0.2414E+00	-0.5298E+00	0.0000E+00	-0.2414E+00	-0.9675E+00	3
21	0.2342E-03	-0.4875E-03	0.0000E+00	0.2342E-03	-0.6300E-02	-0.2411E+00	-0.5300E+00	0.0000E+00	-0.2411E+00	-0.9676E+00	3
22	0.2454E-03	-0.5109E-03	0.0000E+00	0.2454E-03	-0.6620E-02	-0.2408E+00	-0.5302E+00	0.0000E+00	-0.2408E+00	-0.9677E+00	3
23	0.2568E-03	-0.5347E-03	0.0000E+00	0.2568E-03	-0.6942E-02	-0.2405E+00	-0.5303E+00	0.0000E+00	-0.2405E+00	-0.9678E+00	3
24	0.2684E-03	-0.5588E-03	0.0000E+00	0.2684E-03	-0.7266E-02	-0.2402E+00	-0.5305E+00	0.0000E+00	-0.2402E+00	-0.9679E+00	3
25	0.2802E-03	-0.5834E-03	0.0000E+00	0.2802E-03	-0.7592E-02	-0.2399E+00	-0.5307E+00	0.0000E+00	-0.2399E+00	-0.9680E+00	3
26	0.2922E-03	-0.6085E-03	0.0000E+00	0.2922E-03	-0.7920E-02	-0.2395E+00	-0.5308E+00	0.0000E+00	-0.2395E+00	-0.9681E+00	3
27	0.3045E-03	-0.6339E-03	0.0000E+00	0.3045E-03	-0.8251E-02	-0.2392E+00	-0.5310E+00	0.0000E+00	-0.2392E+00	-0.9682E+00	3
28	0.3169E-03	-0.6599E-03	0.0000E+00	0.3169E-03	-0.8584E-02	-0.2389E+00	-0.5312E+00	0.0000E+00	-0.2389E+00	-0.9683E+00	3
29	0.3296E-03	-0.6864E-03	0.0000E+00	0.3296E-03	-0.8920E-02	-0.2386E+00	-0.5313E+00	0.0000E+00	-0.2386E+00	-0.9684E+00	3
30	0.3426E-03	-0.7134E-03	0.0000E+00	0.3426E-03	-0.9258E-02	-0.2382E+00	-0.5315E+00	0.0000E+00	-0.2382E+00	-0.9685E+00	3
31	0.3559E-03	-0.7409E-03	0.0000E+00	0.3559E-03	-0.9599E-02	-0.2379E+00	-0.5316E+00	0.0000E+00	-0.2379E+00	-0.9686E+00	3
32	0.3694E-03	-0.7690E-03	0.0000E+00	0.3694E-03	-0.9943E-02	-0.2376E+00	-0.5318E+00	0.0000E+00	-0.2376E+00	-0.9687E+00	3

33	0.3832E-03	-0.7977E-03	0.0000E+00	0.3832E-03	-0.1029E-01	-0.2372E+00	-0.5319E+00	0.0000E+00	-0.2372E+00	-0.9689E+00	3
34	0.3974E-03	-0.8271E-03	0.0000E+00	0.3974E-03	-0.1064E-01	-0.2369E+00	-0.5321E+00	0.0000E+00	-0.2369E+00	-0.9690E+00	3
35	0.4118E-03	-0.8571E-03	0.0000E+00	0.4118E-03	-0.1099E-01	-0.2363E+00	-0.5323E+00	0.0000E+00	-0.2363E+00	-0.9692E+00	3
36	0.4223E-03	-0.8793E-03	0.0000E+00	0.4223E-03	-0.1139E-01	-0.2361E+00	-0.5324E+00	0.0000E+00	-0.2361E+00	-0.9692E+00	3
37	0.4352E-03	-0.9062E-03	0.0000E+00	0.4352E-03	-0.1173E-01	-0.2358E+00	-0.5325E+00	0.0000E+00	-0.2358E+00	-0.9694E+00	3
38	0.4496E-03	-0.9360E-03	0.0000E+00	0.4496E-03	-0.1208E-01	-0.2352E+00	-0.5327E+00	0.0000E+00	-0.2352E+00	-0.9695E+00	3
39	0.4607E-03	-0.9595E-03	0.0000E+00	0.4607E-03	-0.1249E-01	-0.2350E+00	-0.5328E+00	0.0000E+00	-0.2350E+00	-0.9696E+00	3
40	0.4745E-03	-0.9882E-03	0.0000E+00	0.4745E-03	-0.1284E-01	-0.2345E+00	-0.5329E+00	0.0000E+00	-0.2345E+00	-0.9698E+00	3
41	0.4859E-03	-0.1012E-02	0.0000E+00	0.4859E-03	-0.1325E-01	-0.2343E+00	-0.5330E+00	0.0000E+00	-0.2343E+00	-0.9699E+00	3
42	0.5003E-03	-0.1042E-02	0.0000E+00	0.5003E-03	-0.1360E-01	-0.2337E+00	-0.5331E+00	0.0000E+00	-0.2337E+00	-0.9701E+00	3
43	0.5125E-03	-0.1068E-02	0.0000E+00	0.5125E-03	-0.1402E-01	-0.2335E+00	-0.5332E+00	0.0000E+00	-0.2335E+00	-0.9702E+00	3
44	0.5277E-03	-0.1099E-02	0.0000E+00	0.5277E-03	-0.1439E-01	-0.2330E+00	-0.5333E+00	0.0000E+00	-0.2330E+00	-0.9704E+00	3
45	0.5408E-03	-0.1127E-02	0.0000E+00	0.5408E-03	-0.1481E-01	-0.2325E+00	-0.5334E+00	0.0000E+00	-0.2325E+00	-0.9705E+00	3
46	0.5535E-03	-0.1154E-02	0.0000E+00	0.5535E-03	-0.1524E-01	-0.2321E+00	-0.5335E+00	0.0000E+00	-0.2321E+00	-0.9707E+00	3
47	0.5664E-03	-0.1181E-02	0.0000E+00	0.5664E-03	-0.1566E-01	-0.2317E+00	-0.5336E+00	0.0000E+00	-0.2317E+00	-0.9709E+00	3
48	0.5798E-03	-0.1209E-02	0.0000E+00	0.5798E-03	-0.1608E-01	-0.2313E+00	-0.5337E+00	0.0000E+00	-0.2313E+00	-0.9710E+00	3
49	0.5937E-03	-0.1238E-02	0.0000E+00	0.5937E-03	-0.1652E-01	-0.2309E+00	-0.5337E+00	0.0000E+00	-0.2309E+00	-0.9712E+00	3
50	0.6082E-03	-0.1269E-02	0.0000E+00	0.6082E-03	-0.1696E-01	-0.2305E+00	-0.5338E+00	0.0000E+00	-0.2305E+00	-0.9714E+00	3
51	0.6235E-03	-0.1301E-02	0.0000E+00	0.6235E-03	-0.1741E-01	-0.2300E+00	-0.5338E+00	0.0000E+00	-0.2300E+00	-0.9716E+00	3
52	0.6397E-03	-0.1335E-02	0.0000E+00	0.6397E-03	-0.1787E-01	-0.2296E+00	-0.5338E+00	0.0000E+00	-0.2296E+00	-0.9717E+00	3
53	0.6569E-03	-0.1370E-02	0.0000E+00	0.6569E-03	-0.1834E-01	-0.2291E+00	-0.5338E+00	0.0000E+00	-0.2291E+00	-0.9719E+00	3
54	0.6753E-03	-0.1409E-02	0.0000E+00	0.6753E-03	-0.1882E-01	-0.2284E+00	-0.5338E+00	0.0000E+00	-0.2284E+00	-0.9722E+00	3
55	0.6908E-03	-0.1442E-02	0.0000E+00	0.6908E-03	-0.1942E-01	-0.2281E+00	-0.5338E+00	0.0000E+00	-0.2281E+00	-0.9724E+00	3
56	0.7099E-03	-0.1481E-02	0.0000E+00	0.7099E-03	-0.1990E-01	-0.2274E+00	-0.5337E+00	0.0000E+00	-0.2274E+00	-0.9727E+00	3
57	0.7280E-03	-0.1520E-02	0.0000E+00	0.7280E-03	-0.2051E-01	-0.2268E+00	-0.5336E+00	0.0000E+00	-0.2268E+00	-0.9730E+00	3
58	0.7474E-03	-0.1560E-02	0.0000E+00	0.7474E-03	-0.2112E-01	-0.2262E+00	-0.5335E+00	0.0000E+00	-0.2262E+00	-0.9733E+00	3
59	0.7693E-03	-0.1606E-02	0.0000E+00	0.7693E-03	-0.2175E-01	-0.2256E+00	-0.5333E+00	0.0000E+00	-0.2256E+00	-0.9736E+00	3
60	0.7951E-03	-0.1660E-02	0.0000E+00	0.7951E-03	-0.2241E-01	-0.2250E+00	-0.5331E+00	0.0000E+00	-0.2250E+00	-0.9739E+00	4

LOAD STEP INFORMATION
ksvtch = 0
ntlmes = 39
dslg = 0.00000000E-01 -1.99999995E-04 0.00000000E-01 0.00000000E-01

61	0.8189E-03	-0.1709E-02	0.0000E+00	0.8189E-03	-0.2289E-01	-0.2245E+00	-0.5329E+00	0.0000E+00	-0.2245E+00	-0.9741E+00	4
62	0.8431E-03	-0.1759E-02	0.0000E+00	0.8431E-03	-0.2332E-01	-0.2241E+00	-0.5327E+00	0.0000E+00	-0.2241E+00	-0.9743E+00	4
63	0.8701E-03	-0.1814E-02	0.0000E+00	0.8701E-03	-0.2374E-01	-0.2237E+00	-0.5325E+00	0.0000E+00	-0.2237E+00	-0.9746E+00	4
64	0.9025E-03	-0.1880E-02	0.0000E+00	0.9025E-03	-0.2415E-01	-0.2233E+00	-0.5323E+00	0.0000E+00	-0.2233E+00	-0.9748E+00	4
65	0.9449E-03	-0.1967E-02	0.0000E+00	0.9449E-03	-0.2458E-01	-0.2229E+00	-0.5321E+00	0.0000E+00	-0.2229E+00	-0.9750E+00	4
66	0.1007E-02	-0.2093E-02	0.0000E+00	0.1007E-02	-0.2503E-01	-0.2225E+00	-0.5318E+00	0.0000E+00	-0.2225E+00	-0.9752E+00	4
67	0.1121E-02	-0.2323E-02	0.0000E+00	0.1121E-02	-0.2550E-01	-0.2222E+00	-0.5316E+00	0.0000E+00	-0.2222E+00	-0.9754E+00	4
68	0.1455E-02	-0.2991E-02	0.0000E+00	0.1455E-02	-0.2595E-01	-0.2221E+00	-0.5315E+00	0.0000E+00	-0.2221E+00	-0.9755E+00	4
69	0.2947E-02	-0.5977E-02	0.0000E+00	0.2947E-02	-0.2630E-01	-0.2221E+00	-0.5315E+00	0.0000E+00	-0.2221E+00	-0.9755E+00	4
70	0.5932E-02	-0.1195E-01	0.0000E+00	0.5932E-02	-0.2652E-01	-0.2221E+00	-0.5314E+00	0.0000E+00	-0.2221E+00	-0.9755E+00	4
71	0.1786E-01	-0.3581E-01	0.0000E+00	0.1786E-01	-0.2673E-01	-0.2221E+00	-0.5314E+00	0.0000E+00	-0.2221E+00	-0.9755E+00	4
72	0.1493E+00	-0.2986E+00	0.0000E+00	0.1493E+00	-0.2694E-01	-0.2221E+00	-0.5314E+00	0.0000E+00	-0.2221E+00	-0.9756E+00	4

OUTPUT FROM CAP (CONTINUED)

CONTENTS OF PLOT.1:

0.0000E+00	0.2650E+00	0.0000E+00	0.2128E+01	0.3060E+00
0.1102E-04	0.2651E+00	0.2881E-03	0.2128E+01	0.3061E+00
0.3355E-04	0.2654E+00	0.1012E-02	0.2130E+01	0.3064E+00
0.5992E-04	0.2661E+00	0.1552E-02	0.2135E+01	0,3073E+00
0.8068E-04	0.2664E+00	0.2128E-02	0.2137E+01	0.3076E+00
0.1061E-03	0.2670E+00	0.2668E-02	0.2142E+01	0.3084E+00
0.1269E-03	0.2673E+00	0.3245E-02	0.2144E+01	0.3087E+00
0.1527E-03	0.2680E+00	0.3788E-02	0.2149E+01	0.3094E+00
0.1740E-03	0.2683E+00	0.4370E-02	0.2151E+01	0.3098E+00
0.2003E-03	0.2689E+00	0.4918E-02	0.2156E+01	0.3105E+00
0.2222E-03	0.2692E+00	0.5506E-02	0.2158E+01	0.3108E+00
0.2491E-03	0.2698E+00	0.6058E-02	0.2162E+01	0.3116E+00
0.2717E-03	0.2701E+00	0.6652E-02	0.2164E+01	0.3119E+00
0.2993E-03	0.2708E+00	0.7209E-02	0.2169E+01	0.3127E+00
0.3225E-03	0.2713E+00	0.7809E-02	0.2173E+01	0.3133E+00
0.3445E-03	0.2716E+00	0.8401E-02	0.2175E+01	0.3136E+00
0.3722E-03	0.2722E+00	0.8962E-02	0.2180E+01	0.3143E+00
0.3962E-03	0.2727E+00	0.9570E-02	0.2184E+01	0.3149E+00
0.4190E-03	0.2732E+00	0.1017E-01	0.2187E+01	0.3154E+00
0.4417E-03	0.2737E+00	0.1077E-01	0.2191E+01	0.3160E+00
0.4645E-03	0.2741E+00	0.1137E-01	0.2194E+01	0.3165E+00
0.4875E-03	0.2746E+00	0.1198E-01	0.2198E+01	0.3171E+00
0.5109E-03	0.2751E+00	0.1259E-01	0.2202E+01	0.3176E+00
0.5347E-03	0.2755E+00	0.1320E-01	0.2205E+01	0.3181E+00
0.5588E-03	0.2760E+00	0.1381E-01	0.2209E+01	0.3187E+00
0.5834E-03	0.2764E+00	0.1443E-01	0.2212E+01	0.3192E+00
0.6085E-03	0.2769E+00	0.1506E-01	0.2216E+01	0.3197E+00
0.6339E-03	0.2774E+00	0.1569E-01	0.2220E+01	0.3203E+00
0.6599E-03	0.2778E+00	0.1632E-01	0.2223E+01	0.3208E+00
0.6864E-03	0.2783E+00	0.1696E-01	0.2227E+01	0.3213E+00
0.7134E-03	0.2787E+00	0.1760E-01	0.2231E+01	0.3219E+00
0.7409E-03	0.2792E+00	0.1825E-01	0.2235E+01	0.3224E+00
0.7690E-03	0.2797E+00	0.1890E-01	0.2238E+01	0.3229E+00
0.7977E-03	0.2801E+00	0.1956E-01	0.2242E+01	0.3235E+00
0.8271E-03	0.2806E+00	0.2023E-01	0.2246E+01	0.3240E+00
0.8571E-03	0.2813E+00	0.2090E-01	0.2252E+01	0.3249E+00
0.8793E-03	0.2817E+00	0.2165E-01	0.2255E+01	0.3252E+00
0.9062E-03	0.2820E+00	0.2231E-01	0.2258E+01	0.3257E+00
0.9360E-03	0.2827E+00	0.2297E-01	0.2264E+01	0.3265E+00
0.9595E-03	0.2830E+00	0.2374E-01	0.2267E+01	0.3268E+00
0.9882E-03	0.2837E+00	0.2441E-01	0.2273E+01	0.3276E+00
0.1012E-02	0.2840E+00	0.2518E-01	0.2275E+01	0.3279E+00
0.1042E-02	0.2846E+00	0.2586E-01	0.2281E+01	0.3286E+00
0.1068E-02	0.2849E+00	0.2666E-01	0.2283E+01	0.3289E+00
0.1099E-02	0.2855E+00	0.2735E-01	0.2289E+01	0.3297E+00
0.1127E-02	0.2860E+00	0.2816E-01	0.2294E+01	0.3303E+00
0.1154E-02	0.2865E+00	0.2896E-01	0.2298E+01	0.3308E+00
0.1181E-02	0.2870E+00	0.2977E-01	0.2303E+01	0.3313E+00
0.1209E-02	0.2874E+00	0.3057E-01	0.2307E+01	0.3319E+00
0.1238E-02	0.2879E+00	0.3140E-01	0.2312E+01	0.3324E+00

OUTPUT FROM CAP (CONTINUED)

CONTENTS OF PLOT.1 (CONTINUED):

0.1269E-02	0.2883E+00	0.3224E-01	0.2316E+01	0.3329E+00
0.1301E-02	0.2887E+00	0.3309E-01	0.2320E+01	0.3334E+00
0.1335E-02	0.2892E+00	0.3397E-01	0.2325E+01	0.3339E+00
0.1370E-02	0.2896E+00	0.3487E-01	0.2330E+01	0.3344E+00
0.1409E-02	0.2903E+00	0.3579E-01	0.2337E+01	0.3352E+00
0.1442E-02	0.2906E+00	0.3691E-01	0.2341E+01	0.3356E+00
0.1481E-02	0.2912E+00	0.3784E-01	0.2347E+01	0.3362E+00
0.1520E-02	0.2917E+00	0.3899E-01	0.2353E+01	0.3368E+00
0.1560E-02	0.2921E+00	0.4015E-01	0.2359E+01	0.3373E+00
0.1606E-02	0.2925E+00	0.4135E-01	0.2364E+01	0.3378E+00
0.1660E-02	0.2929E+00	0.4261E-01	0.2369E+01	0.3382E+00
0.1709E-02	0.2932E+00	0.4352E-01	0.2374E+01	0.3385E+00
0.1759E-02	0.2934E+00	0.4434E-01	0.2377E+01	0.3388E+00
0.1814E-02	0.2936E+00	0.4513E-01	0.2381E+01	0.3390E+00
0.1880E-02	0.2937E+00	0.4592E-01	0.2384E+01	0.3392E+00
0.1967E-02	0.2939E+00	0.4673E-01	0.2387E+01	0.3393E+00
0.2093E-02	0.2940E+00	0.4758E-01	0.2390E+01	0.3394E+00
0.2323E-02	0.2940E+00	0.4847E-01	0.2392E+01	0.3395E+00
0.2991E-02	0.2941E+00	0.4934E-01	0.2393E+01	0.3396E+00
0.5977E-02	0.2941E+00	0.5000E-01	0.2393E+01	0.3396E+00
0.1195E-01	0.2941E+00	0.5042E-01	0.2393E+01	0.3396E+00
0.3581E-01	0.2941E+00	0.5083E-01	0.2393E+01	0.3396E+00
0.2986E+00	0.2941E+00	0.5122E-01	0.2393E+01	0.3396E+00

CONTENTS OF PLOT.2:

0.0000E+00	0.3866E+00	0.1394E+00	0.1020E+01	0.1610E+00
0.1102E-04	0.3866E+00	0.1394E+00	0.1020E+01	0.1610E+00
0.3355E-04	0.3866E+00	0.1396E+00	0.1020E+01	0.1612E+00
0.5992E-04	0.3865E+00	0.1400E+00	0.1020E+01	0.1616E+00
0.8068E-04	0.3865E+00	0.1401E+00	0.1019E+01	0.1618E+00
0.1061E-03	0.3864E+00	0.1405E+00	0.1019E+01	0.1622E+00
0.1269E-03	0.3864E+00	0.1406E+00	0.1019E+01	0.1624E+00
0.1527E-03	0.3863E+00	0.1410E+00	0.1018E+01	0.1628E+00
0.1740E-03	0.3863E+00	0.1411E+00	0.1018E+01	0.1629E+00
0.2003E-03	0.3863E+00	0.1414E+00	0.1017E+01	0.1633E+00
0.2222E-03	0.3862E+00	0.1416E+00	0.1017E+01	0.1635E+00
0.2491E-03	0.3862E+00	0.1419E+00	0.1017E+01	0.1639E+00
0.2717E-03	0.3861E+00	0.1421E+00	0.1016E+01	0.1641E+00
0.2993E-03	0.3861E+00	0.1424E+00	0.1016E+01	0.1645E+00
0.3225E-03	0.3860E+00	0.1427E+00	0.1015E+01	0.1648E+00
0.3445E-03	0.3860E+00	0.1428E+00	0.1015E+01	0.1649E+00
0.3722E-03	0.3859E+00	0.1432E+00	0.1014E+01	0.1653E+00
0.3962E-03	0.3858E+00	0.1434E+00	0.1014E+01	0.1656E+00
0.4190E-03	0.3857E+00	0.1437E+00	0.1014E+01	0.1659E+00
0.4417E-03	0.3857E+00	0.1439E+00	0.1013E+01	0.1662E+00
0.4645E-03	0.3856E+00	0.1442E+00	0.1013E+01	0.1665E+00
0.4875E-03	0.3856E+00	0.1444E+00	0.1012E+01	0.1668E+00
0.5109E-03	0.3855E+00	0.1447E+00	0.1012E+01	0.1671E+00

OUTPUT FROM CAP (CONTINUED)

CONTENTS OF PLOT.2 (CONTINUED):

0.5347E-03	0.3854E+00	0.1449E+00	0.1011E+01	0.1673E+00
0.5588E-03	0.3853E+00	0.1452E+00	0.1011E+01	0.1676E+00
0.5834E-03	0.3853E+00	0.1454E+00	0.1010E+01	0,1679E+00
0.6085E-03	0.3852E+00	0.1456E+00	0.1010E+01	0.1682E+00
0.6339E-03	0.3851E+00	0.1459E+00	0.1009E+01	0.1685E+00
0.6599E-03	0.3850E+00	0.1461E+00	0.1009E+01	0.1687E+00
0.6864E-03	0.3849E+00	0.1464E+00	0.1008E+01	0.1690E+00
0.7134E-03	0.3849E+00	0.1466E+00	0.1008E+01	0.1693E+00
0.7409E-03	0.3848E+00	0.1469E+00	0.1007E+01	0.1696E+00
0.7690E-03	0.3847E+00	0.1471E+00	0.1007E+01	0.1699E+00
0.7977E-03	0.3846E+00	0.1473E+00	0.1006E+01	0.1701E+00
0.8271E-03	0.3845E+00	0.1476E+00	0.1006E+01	0.1704E+00
0.8571E-03	0.3843E+00	0.1480E+00	0.1005E+01	0.1709E+00
0.8793E-03	0.3842E+00	0.1481E+00	0.1005E+01	0.1711E+00
0.9062E-03	0.3841E+00	0.1483E+00	0.1004E+01	0.1713E+00
0.9360E-03	0.3840E+00	0.1487E+00	0.1003E+01	0.1717E+00
0.9595E-03	0.3839E+00	0.1489E+00	0.1003E+01	0.1719E+00
0.9882E-03	0.3837E+00	0.1492E+00	0.1002E+01	0.1723E+00
0.1012E-02	0.3836E+00	0.1494E+00	0.1002E+01	0.1725E+00
0.1042E-02	0.3834E+00	0.1497E+00	0.1001E+01	0.1729E+00
0.1068E-02	0.3834E+00	0.1498E+00	0.1000E+01	0.1730E+00
0.1099E-02	0.3832E+00	0.1502E+00	0.9993E+00	0.1734E+00
0.1127E-02	0.3830E+00	0.1504E+00	0.9985E+00	0.1737E+00
0.1154E-02	0.3828E+00	0.1507E+00	0.9978E+00	0.1740E+00
0.1181E-02	0.3827E+00	0.1509E+00	0.9970E+00	0.1743E+00
0.1209E-02	0.3825E+00	0.1512E+00	0.9963E+00	0.1746E+00
0.1238E-02	0.3823E+00	0.1514E+00	0.9955E+00	0.1748E+00
0.1269E-02	0.3821E+00	0.1516E+00	0.9947E+00	0.1751E+00
0.1301E-02	0.3819E+00	0.1519E+00	0.9939E+00	0.1754E+00
0.1335E-02	0.3817E+00	0.1521E+00	0.9930E+00	0.1756E+00
0.1370E-02	0.3815E+00	0.1523E+00	0.9921E+00	0.1759E+00
0.1409E-02	0.3811E+00	0.1527E+00	0.9906E+00	0.1763E+00
0.1442E-02	0.3809E+00	0.1529E+00	0.9899E+00	0.1765E+00
0.1481E-02	0.3805E+00	0.1532E+00	0.9884E+00	0.1769E+00
0.1520E-02	0.3802E+00	0.1534E+00	0.9871E+00	0.1771E+00
0.1560E-02	0.3798E+00	0.1536E+00	0.9859E+00	0.1774E+00
0.1606E-02	0.3795E+00	0.1539E+00	0.9845E+00	0.1777E+00
0.1660E-02	0.3790E+00	0.1541E+00	0.9831E+00	0.1779E+00
0.1709E-02	0.3787E+00	0.1542E+00	0.9819E+00	0.1781E+00
0.1759E-02	0.3784E+00	0.1543E+00	0.9809E+00	0.1782E+00
0.1814E-02	0.3781E+00	0.1544E+00	0.9799E+00	0.1783E+00
0.1880E-02	0.3778E+00	0.1545E+00	0.9789E+00	0.1784E+00
0.1967E-02	0.3775E+00	0.1546E+00	0.9779E+00	0.1785E+00
0.2093E-02	0.3772E+00	0.1546E+00	0.9769E+00	0.1785E+00
0.2323E-02	0.3769E+00	0.1547E+00	0.9760E+00	0.1786E+00
0.2991E-02	0.3768E+00	0.1547E+00	0.9756E+00	0.1786E+00
0.5977E-02	0.3768E+00	0.1547E+00	0.9756E+00	0.1786E+00
0.1195E-01	0.3768E+00	0.1547E+00	0.9756E+00	0.1786E+00
0.3581E-01	0.3767E+00	0.1547E+00	0.9756E+00	0.1786E+00
0.2986E+00	0.3768E+00	0.1547E+00	0.9756E+00	0.1786E+00

APPENDIX E.2

INPUT TO PROGRAM AUTOGEN

INPUT TO AUTOGEN

Items in parentheses are comments added to explain the commands and are not part of the input file.

```
  193   52      (card 1, number of nodes and elements)
NFAP            (control information)
EXAMPLE EMB - 90' BASE WIDTH - 2:1 SLOPE - WEAK CRUST - 1.875' LIFTS
  193        0    2    1    1    2    1      15930    1
    1    0    1   15    1                .01
0.         .5         1.
    0    1             0
JOINT           (input coordinates of selected nodes)
    1            0.        0.
   10            7.5       0.
  136            0.        0.9375
  148            7.5       1.875
  184           35.625     1.875
  187           43.125     0.9375
MSHGN           (generate foundation and some embankment nodes)
    1   10   14       15.      9    1   -3.75
   10    9   14       15.      5    1   -7.5
  136    3   18       15.     12    1    0.9375
  148    2   18       15.      6    1    1.875
JTGEN           (generate more embankment nodes)
  179    5    1 -1.875     0.9375
  184.   3    1 -1.875     1.875
  187    7    1 -1.875     0.9375
JOINT           (redefine nodes 170 and 171)
  170           20.625     9.375
  171           18.75     11.25
JTFIX           (specify fixed degrees of freedom)
    0    1    0    1    8  127  134  136  147
    1    1    1    9   14   23   28   37   42   51   56   65   70   79   84   93
    1    1    1   98  107  112  121  126  135
NFAP            (load control and 2-d element data)
  135    7    4                                  0
   2  52   4               8            2                   10   10   22   12
    1
  98.      1.0      2.116     1.        0.0       0.46      0.172     0.0001
0.146      1.19     0.747    -0.740     0.1       2.0       0.053       0.0
0.6        0.       -10.      0.        0.        0.
    2
  98.      1.0      2.116     1.        0.0       0.46      0.183     0.0001
0.146      0.806    0.747    +1.        0.1       1.        0.053       0.0
0.47       0.       10.       0.        0.        0.
    3
98.0       1.0      2.116      1.        0.0       0.46      0.183     0.0001
0.146      0.484    0.747     +1.0       0.1       1.0       0.053     0.0
0.47       0.0      10.        0.0       0.0       0.0       0.0
    4
98.0       1.0      2.116     1.         0.0       0.46      0.183     0.0001
0.146      0.346    0.747     +1.0       0.1       1.0       0.053     0.0
0.47       0.0      10.        0.0       0.0       0.0       0.0
```

INPUT TO AUTOGEN (CONTINUED)

```
    5
190.       0.65      2.116     20.        0.0       0.33     0.17       0.0001
1.         1.        1.                 -1.E9 .01   2.
                               0.01         .125     .0624
    6
190.       0.65      2.116     20.        0.0       0.33     0.17       0.0001
1.         1.        1.                 -1.E9 .01   2.
                               1.           .125     .0624
    7
190.       0.65      2.116     20.        0.0       0.33     0.17       0.0001
1.         1.        1.                 -1.E9 .01   2.
                               2.           .125     .0624
    8
190.       0.65      2.116     20.        0.0       0.33     0.17       0.0001
1.         1.        1.                 -1.E9 .01   2.
                                3.          .125     .0624
    9
190.       0.65      2.116     20.        0.0       0.33     0.17       0.0001
1.         1.        1.                 -1.E9 .01   2.
                                4.          .125     .0624
   10
190.       0.65      2.116     20.        0.0       0.33     0.17       0.0001
1.         1.        1.                 -1.E9 .01   2.
                                5.          .125     .0624
ELEME           (define selected 2-d elements)
    1    1    1
   15    1    3   17   10    2   11   16
    2    1    2
   17    3    5   19   11    4   12   18
    3    1    3
   19    5    7   21   12    6   13   20
    4    1    4
   21    7    9   23   13    8   14   22
   37    1    5
  155  137    1   15  148  136   10  154
   38    1    6
  157  139  137  155  149  138  148  156
   39    1    7
  159  141  139  157  150  140  149  158
   40    1    8
  161  143  141  159  151  142  150  160
   41    1    9
  163  145  143  161  152  144  151  162
   42    1   10
  165  147  145  163  153  146  152  164
   43    1    5
  173  155   15   29  166  154   24  172
   49    1    5
  188  173   29   43  184  172   38  187
   50    1    6
  190  175  173  188  185  174  184  189
   51    1    7
  192  177  175  190  186  176  185  191
```

INPUT TO AUTOGEN (CONTINUED)

```
   52    1    8
  179  179  177  192  179  178  186  193
ELSTR           (generate foundation elements)
    1    9    4   14   14   14   14   14   14   14   14
    2    9    4   14   14   14   14   14   14   14   14
    3    9    4   14   14   14   14   14   14   14   14
    4    9    4   14   14   14   14   14   14   14   14
ELDUP           (generate embankment elements 44 through 48)
   38   42    6   18
NFAP            (truss element data and load curves)
    1  3  2                                                2   1   6
    1                 1.        0.        0.
-1.       -0.0001     1.        0.        .0001     60.
    1    1   10   15    1
    2   15   24   29    1
    3   29   38   43    1
    1    2                                (load curve 1)
0.         -1.        10.       -1.       (load curve 1)
    2    3
0.         0.         1.        -1.       10.       -1.
    3    4
0.         0.         1.        0.        2.        -1.       10.       -1.
    4    4
0.         0.         2.        0.        3.        -1.       10.       -1.
    5    4
0.         0.         3.        0.        4.        -1.       10.       -1.
    6    4
0.         0.         4.        0.        5.        -1.       10.       -1.
    7    4
0.         0.         5.        0.        6.        -1.       10.       -1.
LOAD            (generate nodal loads to balance initial stress in foundation)
         1        1
         1       36     0.053          2         3
FOLL            (last card)
```

APPENDIX E.3

INPUT TO PROGRAM PS-NFAP

INPUT TO PS-NFAP

```
EXAMPLE EMB - 90' BASE WIDTH - 2:1 SLOPE - WEAK CRUST - 1.875' LIFTS
  193         0    2    1    1    2    1      15930    1
    1    0    1   15    1                .01
0.        .5        1.
    0    1                0
    10   0    1    0 (note: 0 added       0.000      0.000      0.000
    2    0    1    0  with text editor;  0.000      0.000     -3.750
    3    0    1    0  not generated      0.000      0.000     -7.500
    4    0    1    0  by AUTOGEN)        0.000      0.000    -11.250
    5    0    1    0                     0.000      0.000    -15.000
    6    0    1    0                     0.000      0.000    -18.750
    7    0    1    0                     0.000      0.000    -22.500
    8    0    1    0                     0.000      0.000    -26.250
    9    0    1    1                     0.000      0.000    -30.000
   10    0    0    0                     0.000      7.500      0.000
   11    0    0    0                     0.000      7.500     -7.500
   12    0    0    0                     0.000      7.500    -15.000
   13    0    0    0                     0.000      7.500    -22.500
   14    0    1    1                     0.000      7.500    -30.000
   15    0    0    0                     0.000     15.000      0.000
   16    0    0    0                     0.000     15.000     -3.750
   17    0    0    0                     0.000     15.000     -7.500
   18    0    0    0                     0.000     15.000    -11.250
   19    0    0    0                     0.000     15.000    -15.000
   20    0    0    0                     0.000     15.000    -18.750
   21    0    0    0                     0.000     15.000    -22.500
   22    0    0    0                     0.000     15.000    -26.250
   23    0    1    1                     0.000     15.000    -30.000
   24    0    0    0                     0.000     22.500      0.000
   25    0    0    0                     0.000     22.500     -7.500
   26    0    0    0                     0.000     22.500    -15.000
   27    0    0    0                     0.000     22.500    -22.500
   28    0    1    1                     0.000     22.500    -30.000
   29    0    0    0                     0.000     30.000      0.000
   30    0    0    0                     0.000     30.000     -3.750
   31    0    0    0                     0.000     30.000     -7.500
   32    0    0    0                     0.000     30.000    -11.250
   33    0    0    0                     0.000     30.000    -15.000
   34    0    0    0                     0.000     30.000    -18.750
   35    0    0    0                     0.000     30.000    -22.500
   36    0    0    0                     0.000     30.000    -26.250
   37    0    1    1                     0.000     30.000    -30.000
   38    0    0    0                     0.000     37.500      0.000
   39    0    0    0                     0.000     37.500     -7.500
   40    0    0    0                     0.000     37.500    -15.000
   41    0    0    0                     0.000     37.500    -22.500
   42    0    1    1                     0.000     37.500    -30.000
   43    0    0    0                     0.000     45.000      0.000
   44    0    0    0                     0.000     45.000     -3.750
   45    0    0    0                     0.000     45.000     -7.500
   46    0    0    0                     0.000     45.000    -11.250
   47    0    0    0                     0.000     45.000    -15.000
   48    0    0    0                     0.000     45.000    -18.750
```

INPUT TO PS-NFAP (CONTINUED)

49	0	0	0	0.000	45.000	-22.500
50	0	0	0	0.000	45.000	-26.250
51	0	1	1	0.000	45.000	-30.000
52	0	0	0	0.000	52.500	0.000
53	0	0	0	0.000	52.500	-7.500
54	0	0	0	0.000	52.500	-15.000
55	0	0	0	0.000	52.500	-22.500
56	0	1	1	0.000	52.500	-30.000
57	0	0	0	0.000	60.000	0.000
58	0	0	0	0.000	60.000	-3.750
59	0	0	0	0.000	60.000	-7.500
60	0	0	0	0.000	60.000	-11.250
61	0	0	0	0.000	60.000	-15.000
62	0	0	0	0.000	60.000	-18.750
63	0	0	0	0.000	60.000	-22.500
64	0	0	0	0.000	60.000	-26.250
65	0	1	1	0.000	60.000	-30.000
66	0	0	0	0.000	67.500	0.000
67	0	0	0	0.000	67.500	-7.500
68	0	0	0	0.000	67.500	-15.000
69	0	0	0	0.000	67.500	-22.500
70	0	1	1	0.000	67.500	-30.000
71	0	0	0	0.000	75.000	0.000
72	0	0	0	0.000	75.000	-3.750
73	0	0	0	0.000	75.000	-7.500
74	0	0	0	0.000	75.000	-11.250
75	0	0	0	0.000	75.000	-15.000
76	0	0	0	0.000	75.000	-18.750
77	0	0	0	0.000	75.000	-22.500
78	0	0	0	0.000	75.000	-26.250
79	0	1	1	0.000	75.000	-30.000
80	0	0	0	0.000	82.500	0.000
81	0	0	0	0.000	82.500	-7.500
82	0	0	0	0.000	82.500	-15.000
83	0	0	0	0.000	82.500	-22.500
84	0	1	1	0.000	82.500	-30.000
85	0	0	0	0.000	90.000	0.000
86	0	0	0	0.000	90.000	-3.750
87	0	0	0	0.000	90.000	-7.500
88	0	0	0	0.000	90.000	-11.250
89	0	0	0	0.000	90.000	-15.000
90	0	0	0	0.000	90.000	-18.750
91	0	0	0	0.000	90.000	-22.500
92	0	0	0	0.000	90.000	-26.250
93	0	1	1	0.000	90.000	-30.000
94	0	0	0	0.000	97.500	0.000
95	0	0	0	0.000	97.500	-7.500
96	0	0	0	0.000	97.500	-15.000
97	0	0	0	0.000	97.500	-22.500
98	0	1	1	0.000	97.500	-30.000
99	0	0	0	0.000	105.000	0.000
100	0	0	0	0.000	105.000	-3.750
101	0	0	0	0.000	105.000	-7.500

INPUT TO PS-NFAP (CONTINUED)

102	0	0	0	0.000	105.000	-11.250
103	0	0	0	0.000	105.000	-15.000
104	0	0	0	0.000	105.000	-18.750
105	0	0	0	0.000	105.000	-22.500
106	0	0	0	0.000	105.000	-26.250
107	0	1	1	0.000	105.000	-30.000
108	0	0	0	0.000	112.500	0.000
109	0	0	0	0.000	112.500	-7.500
110	0	0	0	0.000	112.500	-15.000
111	0	0	0	0.000	112.500	-22.500
112	0	1	1	0.000	112.500	-30.000
113	0	0	0	0.000	120.000	0.000
114	0	0	0	0.000	120.000	-3.750
115	0	0	0	0.000	120.000	-7.500
116	0	0	0	0.000	120.000	-11.250
117	0	0	0	0.000	120.000	-15.000
118	0	0	0	0.000	120.000	-18.750
119	0	0	0	0.000	120.000	-22.500
120	0	0	0	0.000	120.000	-26.250
121	0	1	1	0.000	120.000	-30.000
122	0	0	0	0.000	127.500	0.000
123	0	0	0	0.000	127.500	-7.500
124	0	0	0	0.000	127.500	-15.000
125	0	0	0	0.000	127.500	-22.500
126	0	1	1	0.000	127.500	-30.000
127	0	1	0	0.000	135.000	0.000
128	0	1	0	0.000	135.000	-3.750
129	0	1	0	0.000	135.000	-7.500
130	0	1	0	0.000	135.000	-11.250
131	0	1	0	0.000	135.000	-15.000
132	0	1	0	0.000	135.000	-18.750
133	0	1	0	0.000	135.000	-22.500
134	0	1	0	0.000	135.000	-26.250
135	0	1	1	0.000	135.000	-30.000
136	0	1	0	0.000	0.000	0.937
137	0	1	0	0.000	0.000	1.875
138	0	1	0	0.000	0.000	2.812
139	0	1	0	0.000	0.000	3.750
140	0	1	0	0.000	0.000	4.687
141	0	1	0	0.000	0.000	5.625
142	0	1	0	0.000	0.000	6.562
143	0	1	0	0.000	0.000	7.500
144	0	1	0	0.000	0.000	8.437
145	0	1	0	0.000	0.000	9.375
146	0	1	0	0.000	0.000	10.312
147	0	1	0	0.000	0.000	11.250
148	0	0	0	0.000	7.500	1.875
149	0	0	0	0.000	7.500	3.750
150	0	0	0	0.000	7.500	5.625
151	0	0	0	0.000	7.500	7.500
152	0	0	0	0.000	7.500	9.375
153	0	0	0	0.000	7.500	11.250
154	0	0	0	0.000	15.000	0.937

INPUT TO PS-NFAP (CONTINUED)

```
  155    0     0     0                      0.000     15.000      1.875
  156    0     0     0                      0.000     15.000      2.812
  157    0     0     0                      0.000     15.000      3.750
  158    0     0     0                      0.000     15.000      4.687
  159    0     0     0                      0.000     15.000      5.625
  160    0     0     0                      0.000     15.000      6.562
  161    0     0     0                      0.000     15.000      7.500
  162    0     0     0                      0.000     15.000      8.437
  163    0     0     0                      0.000     15.000      9.375
  164    0     0     0                      0.000     15.000     10.312
  165    0     0     0                      0.000     15.000     11.250
  166    0     0     0                      0.000     22.500      1.875
  167    0     0     0                      0.000     22.500      3.750
  168    0     0     0                      0.000     22.500      5.625
  169    0     0     0                      0.000     22.500      7.500
  170    0     0     0                      0.000     20.625      9.375
  171    0     0     0                      0.000     18.750     11.250
  172    0     0     0                      0.000     30.000      0.937
  173    0     0     0                      0.000     30.000      1.875
  174    0     0     0                      0.000     30.000      2.812
  175    0     0     0                      0.000     30.000      3.750
  176    0     0     0                      0.000     30.000      4.687
  177    0     0     0                      0.000     30.000      5.625
  178    0     0     0                      0.000     30.000      6.562
  179    0     0     0                      0.000     30.000      7.500
  180    0     0     0                      0.000     28.125      8.437
  181    0     0     0                      0.000     26.250      9.375
  182    0     0     0                      0.000     24.375     10.312
  183    0     0     0                      0.000     22.500     11.250
  184    0     0     0                      0.000     35.625      1.875
  185    0     0     0                      0.000     33.750      3.750
  186    0     0     0                      0.000     31.875      5.625
  187    0     0     0                      0.000     43.125      0.937
  188    0     0     0                      0.000     41.250      1.875
  189    0     0     0                      0.000     39.375      2.812
  190    0     0     0                      0.000     37.500      3.750
  191    0     0     0                      0.000     35.625      4.687
  192    0     0     0                      0.000     33.750      5.625
  193    0     0     0                      0.000     31.875      6.562
  135    7     4                                 0
   2  52    4              8          2                    10  10  22  12
    1
  98.      1.0        2.116     1.        0.0        0.46       0.172     0.0001
0.146      1.19       0.747     -0.740    0.1        2.0        0.053        0.0
0.6        0.         -10.      0.        0.         0.
    2
  98.      1.0        2.116     1.        0.0        0.46       0.183     0.0001
0.146      0.806      0.747     +1.       0.1        1.         0.053        0.0
0.47       0.         10.       0.        0.         0.
```

INPUT TO PS-NFAP (CONTINUED)

```
    3
98.0      1.0       2.116      1.        0.0       0.46       0.183    0.0001
0.146     0.484     0.747      +1.0      0.1       1.0        0.053    0.0
0.47      0.0       10.        0.0       0.0       0.0        0.0
    4
98.0      1.0       2.116      1.        0.0       0.46       0.183    0.0001
0.146     0.346     0.747      +1.0      0.1       1.0        0.053    0.0
0.47      0.0       10.        0.0       0.0       0.0        0.0
    5
190.      0.65      2.116      20.       0.0       0.33       0.17     0.0001
1.        1.        1.              -1.E9 .01      2.
                               0.01      .125       .0624
    6
190.      0.65      2.116      20.       0.0       0.33       0.17     0.0001
1.        1.        1.              -1.E9 .01      2.
                               1.        .125       .0624
    7
190.      0.65      2.116      20.       0.0       0.33       0.17     0.0001
1.        1.        1.              -1.E9 .01      2.
                               2.        .125       .0624
    8
190.      0.65      2.116      20.       0.0       0.33       0.17     0.0001
1.        1.        1.              -1.E9 .01      2.
                               3.        .125       .0624
    9
190.      0.65      2.116      20.       0.0       0.33       0.17     0.0001
1.        1.        1.              -1.E9 .01      2.
                               4.        .125       .0624
   10
190.      0.65      2.116      20.       0.0       0.33       0.17     0.0001
1.        1.        1.              -1.E9 .01      2.
                               5.        .125       .0624
    1    8    1    1              0.000      0.000
   15    1    3   17   10    2   11   16
    2    8    1    2              0.000      0.000
   17    3    5   19   11    4   12   18
    3    8    1    3              0.000      0.000
   19    5    7   21   12    6   13   20
    4    8    1    4              0.000      0.000
   21    7    9   23   13    8   14   22
    5    8    1    1              0.000      0.000
   29   15   17   31   24   16   25   30
    6    8    1    2              0.000      0.000
   31   17   19   33   25   18   26   32
    7    8    1    3              0.000      0.000
   33   19   21   35   26   20   27   34
    8    8    1    4              0.000      0.000
   35   21   23   37   27   22   28   36
    9    8    1    1              0.000      0.000
   43   29   31   45   38   30   39   44
   10    8    1    2              0.000      0.000
   45   31   33   47   39   32   40   46
```

INPUT TO PS-NFAP (CONTINUED)

11	8	1	3				0.000	0.000
47	33	35	49	40	34	41	48	
12	8	1	4				0.000	0.000
49	35	37	51	41	36	42	50	
13	8	1	1				0.000	0.000
57	43	45	59	52	44	53	58	
14	8	1	2				0.000	0.000
59	45	47	61	53	46	54	60	
15	8	1	3				0.000	0.000
61	47	49	63	54	48	55	62	
16	8	1	4				0.000	0.000
63	49	51	65	55	50	56	64	
17	8	1	1				0.000	0.000
71	57	59	73	66	58	67	72	
18	8	1	2				0.000	0.000
73	59	61	75	67	60	68	74	
19	8	1	3				0.000	0.000
75	61	63	77	68	62	69	76	
20	8	1	4				0.000	0.000
77	63	65	79	69	64	70	78	
21	8	1	1				0.000	0.000
85	71	73	87	80	72	81	86	
22	8	1	2				0.000	0.000
87	73	75	89	81	74	82	88	
23	8	1	3				0.000	0.000
89	75	77	91	82	76	83	90	
24	8	1	4				0.000	0.000
91	77	79	93	83	78	84	92	
25	8	1	1				0.000	0.000
99	85	87	101	94	86	95	100	
26	8	1	2				0.000	0.000
101	87	89	103	95	88	96	102	
27	8	1	3				0.000	0.000
103	89	91	105	96	90	97	104	
28	8	1	4				0.000	0.000
105	91	93	107	97	92	98	106	
29	8	1	1				0.000	0.000
113	99	101	115	108	100	109	114	
30	8	1	2				0.000	0.000
115	101	103	117	109	102	110	116	
31	8	1	3				0.000	0.000
117	103	105	119	110	104	111	118	
32	8	1	4				0.000	0.000
119	105	107	121	111	106	112	120	
33	8	1	1				0.000	0.000
127	113	115	129	122	114	123	128	
34	8	1	2				0.000	0.000
129	115	117	131	123	116	124	130	
35	8	1	3				0.000	0.000
131	117	119	133	124	118	125	132	
36	8	1	4				0.000	0.000
133	119	121	135	125	120	126	134	

INPUT TO PS-NFAP (CONTINUED)

```
   37    8    1    5                 0.000       0.000
  155  137    1   15  148  136   10  154
   38    8    1    6                 0.000       0.000
  157  139  137  155  149  138  148  156
   39    8    1    7                 0.000       0.000
  159  141  139  157  150  140  149  158
   40    8    1    8                 0.000       0.000
  161  143  141  159  151  142  150  160
   41    8    1    9                 0.000       0.000
  163  145  143  161  152  144  151  162
   42    8    1   10                 0.000       0.000
  165  147  145  163  153  146  152  164
   43    8    1    5                 0.000       0.000
  173  155   15   29  166  154   24  172
   44    8    1    6                 0.000       0.000
  175  157  155  173  167  156  166  174
   45    8    1    7                 0.000       0.000
  177  159  157  175  168  158  167  176
   46    8    1    8                 0.000       0.000
  179  161  159  177  169  160  168  178
   47    8    1    9                 0.000       0.000
  181  163  161  179  170  162  169  180
   48    8    1   10                 0.000       0.000
  183  165  163  181  171  164  170  182
   49    8    1    5                 0.000       0.000
  188  173   29   43  184  172   38  187
   50    8    1    6                 0.000       0.000
  190  175  173  188  185  174  184  189
   51    8    1    7                 0.000       0.000
  192  177  175  190  186  176  185  191
   52    8    1    8                 0.000       0.000
  179  179  177  192  179  178  186  193
    1   3   2                                                 2    1    6
    1                 1.         0.         0.
-1.        -0.0001    1.         0.         .0001      60.
    1    1   10   15    1
    2   15   24   29    1
    3   29   38   43    1
    1    2
0.         -1.        10.        -1.
    2    3
0.          0.         1.        -1.        10.        -1.
    3    4
0.          0.         1.         0.         2.        -1.        10.       -1.
    4    4
0.          0.         2.         0.         3.        -1.        10.       -1.
    5    4
0.          0.         3.         0.         4.        -1.        10.       -1.
    6    4
0.          0.         4.         0.         5.        -1.        10.       -1.
    7    4
0.          0.         5.         0.         6.        -1.        10.       -1.
```

INPUT TO PS-NFAP (CONTINUED)

1	3	1-.4969E+00
2	3	10.1987E+01
3	3	1-.9937E+00
4	3	10.1987E+01
5	3	1-.9937E+00
6	3	10.1987E+01
7	3	1-.9938E+00
8	3	10.1987E+01
9	3	1-.4969E+00
10	3	10.1987E+01
11	3	10.3975E+01
12	3	10.3975E+01
13	3	10.3975E+01
14	3	10.1987E+01
15	3	1-.9937E+00
16	3	10.3975E+01
17	3	1-.1987E+01
18	3	10.3975E+01
19	3	1-.1987E+01
20	3	10.3975E+01
21	3	1-.1987E+01
22	3	10.3975E+01
23	3	1-.9937E+00
24	3	10.1987E+01
25	3	10.3975E+01
26	3	10.3975E+01
27	3	10.3975E+01
28	3	10.1987E+01
29	3	1-.9937E+00
30	3	10.3975E+01
31	3	1-.1987E+01
32	3	10.3975E+01
33	3	1-.1987E+01
34	3	10.3975E+01
35	3	1-.1987E+01
36	3	10.3975E+01
37	3	1-.9937E+00
38	3	10.1987E+01
39	3	10.3975E+01
40	3	10.3975E+01
41	3	10.3975E+01
42	3	10.1987E+01
43	3	1-.9938E+00
44	3	10.3975E+01
45	3	1-.1987E+01
46	3	10.3975E+01
47	3	1-.1987E+01
48	3	10.3975E+01
49	3	1-.1987E+01
50	3	10.3975E+01
51	3	1-.9937E+00
52	3	10.1987E+01
53	3	10.3975E+01

INPUT TO PS-NFAP (CONTINUED)

54	3	10.3975E+01
55	3	10.3975E+01
56	3	10.1987E+01
57	3	1-.9937E+00
58	3	10.3975E+01
59	3	1-.1987E+01
60	3	10.3975E+01
61	3	1-.1987E+01
62	3	10.3975E+01
63	3	1-.1987E+01
64	3	10.3975E+01
65	3	1-.9937E+00
66	3	10.1987E+01
67	3	10.3975E+01
68	3	10.3975E+01
69	3	10.3975E+01
70	3	10.1987E+01
71	3	1-.9938E+00
72	3	10.3975E+01
73	3	1-.1987E+01
74	3	10.3975E+01
75	3	1-.1987E+01
76	3	10.3975E+01
77	3	1-.1987E+01
78	3	10.3975E+01
79	3	1-.9937E+00
80	3	10.1987E+01
81	3	10.3975E+01
82	3	10.3975E+01
83	3	10.3975E+01
84	3	10.1987E+01
85	3	1-.9937E+00
86	3	10.3975E+01
87	3	1-.1988E+01
88	3	10.3975E+01
89	3	1-.1987E+01
90	3	10.3975E+01
91	3	1-.1987E+01
92	3	10.3975E+01
93	3	1-.9937E+00
94	3	10.1988E+01
95	3	10.3975E+01
96	3	10.3975E+01
97	3	10.3975E+01
98	3	10.1988E+01
99	3	1-.9937E+00
100	3	10.3975E+01
101	3	1-.1988E+01
102	3	10.3975E+01
103	3	1-.1987E+01
104	3	10.3975E+01
105	3	1-.1988E+01
106	3	10.3975E+01

INPUT TO PS-NFAP (CONTINUED)

107	3	1-.9938E+00	
108	3	10.1987E+01	
109	3	10.3975E+01	
110	3	10.3975E+01	
111	3	10.3975E+01	
112	3	10.1987E+01	
113	3	1-.9938E+00	
114	3	10.3975E+01	
115	3	1-.1987E+01	
116	3	10.3975E+01	
117	3	1-.1987E+01	
118	3	10.3975E+01	
119	3	1-.1987E+01	
120	3	10.3975E+01	
121	3	1-.9937E+00	
122	3	10.1987E+01	
123	3	10.3975E+01	
124	3	10.3975E+01	
125	3	10.3975E+01	
126	3	10.1988E+01	
127	3	1-.4969E+00	
128	3	10.1987E+01	
129	3	1-.9937E+00	
130	3	10.1987E+01	
131	3	1-.9937E+00	
132	3	10.1987E+01	
133	3	1-.9937E+00	
134	3	10.1987E+01	
135	3	1-.4969E+00	TOTAL Z - DIR LOAD = 0.2146500E+03 NCARD = 135

APPENDIX E.4

OUTPUT FROM PROGRAM NFMINX

[illegible]

OUTPUT FROM NFMINX

```
BANDWIDTH MINIMIZATION IS PERFORMED FOR PROBLEM9

    EXAMPLE EMB - 90' BASE WIDTH - 2:1 SLOPE - WEAK CRUST - 1.875' LIFTS

TOTAL AVAILABLE CORE STORAGE  =     14990

MAX AVAILABLE DEGREE PER NODE =        64

MAX DEGREE FOR THE PROBLEM =        32

MAX NON ZERO STIFFNESS     =     2904

ORIGINAL BANDWIDTH =    159  ORIGINAL PROFILE =  3914

FINAL BANDWIDTH =    34  FINAL PROFILE =  2512
```

OUTPUT FROM NFMINX (CONTINUED)

OLD NODE / NEW NODE TABLE

OLD NODE	NEW NODE	OLD NODE	NEW NODE	OLD NODE	NEW NODE	OLD NODE	NEW NODE	OLD NODE	NEW NODE
1	53	2	56	3	55	4	51	5	50
6	45	7	44	8	28	9	27	10	52
11	54	12	49	13	43	14	26	15	77
16	81	17	78	18	76	19	74	20	62
21	60	22	58	23	57	24	79	25	80
26	75	27	61	28	59	29	96	30	100
31	97	32	90	33	88	34	87	35	85
36	83	37	82	38	98	39	99	40	89
41	86	42	84	43	111	44	113	45	110
46	109	47	107	48	106	49	104	50	102
51	101	52	114	53	112	54	108	55	105
56	103	57	127	58	126	59	124	60	123
61	121	62	120	63	118	64	116	65	115
66	128	67	125	68	122	69	119	70	117
71	152	72	151	73	149	74	148	75	146
76	145	77	143	78	130	79	129	80	153
81	150	82	147	83	144	84	131	85	171
86	170	87	168	88	167	89	165	90	156
91	154	92	133	93	132	94	172	95	169
96	166	97	155	98	134	99	184	100	183
101	181	102	175	103	173	104	159	105	157
106	136	107	135	108	185	109	182	110	174
111	158	112	137	113	190	114	189	115	186
116	179	117	176	118	163	119	160	120	139
121	138	122	193	123	188	124	178	125	162
126	142	127	192	128	191	129	187	130	180
131	177	132	164	133	161	134	141	135	140
136	48	137	47	138	42	139	41	140	31
141	30	142	19	143	18	144	11	145	10
146	3	147	2	148	46	149	40	150	29
151	17	152	9	153	1	154	73	155	71
156	65	157	63	158	34	159	32	160	22
161	20	162	15	163	12	164	5	165	4
166	72	167	64	168	33	169	21	170	14
171	8	172	94	173	91	174	69	175	66
176	36	177	35	178	24	179	23	180	16
181	13	182	7	183	6	184	93	185	68
186	38	187	95	188	92	189	70	190	67
191	39	192	37	193	25				

[illegible]TPU[illegible]RO[illegible]FM[illegible](C[illegible]INU[illegible]).

NEW NODE / OLD NODE TABLE

NEW NODE	OLD NODE	NEW NODE	OLD NODE	NEW NODE	OLD NODE	NEW NODE	OLD NODE	NEW NODE	OLD NODE
1	153	2	147	3	146	4	165	5	164
6	183	7	182	8	171	9	152	10	145
11	144	12	163	13	181	14	170	15	162
16	180	17	151	18	143	19	142	20	161
21	169	22	160	23	179	24	178	25	193
26	14	27	9	28	8	29	150	30	141
31	140	32	159	33	168	34	158	35	177
36	176	37	192	38	186	39	191	40	149
41	139	42	138	43	13	44	7	45	6
46	148	47	137	48	136	49	12	50	5
51	4	52	10	53	1	54	11	55	3
56	2	57	23	58	22	59	28	60	21
61	27	62	20	63	157	64	167	65	156
66	175	67	190	68	185	69	174	70	189
71	155	72	166	73	154	74	19	75	26
76	18	77	15	78	17	79	24	80	25
81	16	82	37	83	36	84	42	85	35
86	41	87	34	88	33	89	40	90	32
91	173	92	188	93	184	94	172	95	187
96	29	97	31	98	38	99	39	100	30
101	51	102	50	103	56	104	49	105	55
106	48	107	47	108	54	109	46	110	45
111	43	112	53	113	44	114	52	115	65
116	64	117	70	118	63	119	69	120	62
121	61	122	68	123	60	124	59	125	67
126	58	127	57	128	66	129	79	130	78
131	84	132	93	133	92	134	98	135	107
136	106	137	112	138	121	139	120	140	135
141	134	142	126	143	77	144	83	145	76
146	75	147	82	148	74	149	73	150	81
151	72	152	71	153	80	154	91	155	97
156	90	157	105	158	111	159	104	160	119
161	133	162	125	163	118	164	132	165	89
166	96	167	88	168	87	169	95	170	86
171	85	172	94	173	103	174	110	175	102
176	117	177	131	178	124	179	116	180	130
181	101	182	109	183	100	184	99	185	108
186	115	187	129	188	123	189	114	190	113
191	128	192	127	193	122				

APPENDIX E.5

OUTPUT FROM PROGRAM PS-NFAP

OUTPUT FROM PS-NFAP

(comments have been added to assist in interpreting the output)

```
EXAMPLE EMB - 90' BASE WIDTH - 2:1 SLOPE - WEAK CRUST - 1.875' LIFTS

C O N T R O L   I N F O R M A T I O N

   NUMBER OF NODAL POINTS . . . . . . . . . . . (NUMNP)   =  193

   NUMBER OF LINEAR ELEMENT GROUPS . . . . . . (NEGL)     =    0

   NUMBER OF NONLINEAR ELEMENT GROUPS . . . .  (NEGNL)    =    2

   SOLUTION MODE . . . . . . . . . . . . . . . (MODEX)    =    1
      EQ.0, DATA CHECK
      EQ.1, EXECUTION
      EQ.2, RESTART

   TOTAL TIME STEP INCREMENT . . . . . . . .  (NSTE)      =    2

   PRINTING INTERVAL . . . . . . . . . . . . . (IPRI)     =    2

   RESTART SAVE INTERVAL . . . . . . . . . . . (IRINT)    =    1

   SPECIFIED BLOCK LENGTH . . . . . . . . . . .(ISTOTE)   =15930

   NUMBER OF TIME STEPS BETWEEN REFORMING
     EFFECTIVE STIFFNESS MATRIX . . . . . . . (ISREF)     =    1

   NUMBER OF ITERATIONS BETWEEN REFORMING STIFFNESS
     IN EACH TIME STEP . . . . . . . . . . . . (NUMREF)   =    0

   NUMBER OF TIME STEPS BETWEEN
     EQUILIBRIUM ITERATIONS . . . . . . . . . (IEQUIT)    =    1

   MAXIMUM NUMBER OF EQUILIBRIUM
     ITERATIONS PERMITTED . . . . . . . . . . (ITEMAX)    =   15

   ACCELERATION CODE . . . . . . . . . . . . . (IACC)     =    1
      EQ.0, NO ACCELERATION PERFORMED
      EQ.1, SECANT ACCELERATION

   DISPLACEMENT CONVERGENCE TOLERANCE . . . . . (RTOL) =  0.10E-01
   FORCE CONVERGENCE TOLERANCE . . . . . . . . . (FTOL) =  0.00E+00
```

OUTPUT FROM PS-NFAP (CONTINUED)

```
A N A L Y S I S   T Y P E

   STATIC ANALYSIS

   NONLINEARITY CODE . . . . . . . . . . . . . . (KLIN)    =    1
      EQ.0, LINEAR ANALYSIS
      EQ.1, NONLINEAR ANALYSIS

P R I N T O U T   C O D E

   NUMBER OF BLOCKS OF NODAL PRINTOUT . . . . . . (NPB) =    1

   DISPLACEMENT PRINTOUT CODE . . . . . . . . . . (IDC) =    1
      EQ.0, NO PRINTING OF DISPLACEMENTS
      EQ.1, PRINT DISPLACEMENTS

   BLOCK  1

      FIRST NODE OF THIS BLOCK  . . . . .  (IPNODE(1,1) =    1

      LAST NODE OF THIS BLOCK . . . . . .  (IPNODE(2,1) =  193

T I M E   S T E P   I N F O R M A T I O N

STARTING TIME     TIME STEP INCREMENT     NUMBER OF TIME STEP

  0.0000E+00          0.5000E+00                   2
```

E4G

OUTPUT FROM PS-NFAP (CONTINUED)

N O D A L   P O I N T   D A T A

INPUT NODAL DATA

OLD NODE	NEW NODE	BOUNDARY CONDITION CODE Y		BOUNDARY CONDITION CODE Z		NODAL POINT COORDINATES Y	NODAL POINT COORDINATES Z	MESH GENERATING CODE KN
1	53	1	(1 =	0	(0 = free)	0.000	0.000	0
2	56	1	fixed)	0		0.000	-3.750	0
3	55	1		0		0.000	-7.500	0
4	51	1		0		0.000	-11.250	0
5	50	1		0		0.000	-15.000	0
6	45	1		0		0.000	-18.750	0
7	44	1		0		0.000	-22.500	0
8	28	1		0		0.000	-26.250	0
9	27	1		1		0.000	-30.000	0
10	52	0		0		7.500	0.000	0
11	54	0		0		7.500	-7.500	0
12	49	0		0		7.500	-15.000	0
13	43	0		0		7.500	-22.500	0
14	26	1		1		7.500	-30.000	0
15	77	0		0		15.000	0.000	0
16	81	0		0		15.000	-3.750	0
17	78	0		0		15.000	-7.500	0
18	76	0		0		15.000	-11.250	0
19	74	0		0		15.000	-15.000	0
20	62	0		0		15.000	-18.750	0
21	60	0		0		15.000	-22.500	0
22	58	0		0		15.000	-26.250	0
23	57	1		1		15.000	-30.000	0
24	79	0		0		22.500	0.000	0
25	80	0		0		22.500	-7.500	0
26	75	0		0		22.500	-15.000	0
27	61	0		0		22.500	-22.500	0
28	59	1		1		22.500	-30.000	0
29	96	0		0		30.000	0.000	0
30	100	0		0		30.000	-3.750	0
31	97	0		0		30.000	-7.500	0
32	90	0		0		30.000	-11.250	0
33	88	0		0		30.000	-15.000	0
34	87	0		0		30.000	-18.750	0
35	85	0		0		30.000	-22.500	0
36	83	0		0		30.000	-26.250	0
37	82	1		1		30.000	-30.000	0
38	98	0		0		37.500	0.000	0
39	99	0		0		37.500	-7.500	0
40	89	0		0		37.500	-15.000	0
41	86	0		0		37.500	-22.500	0
42	84	1		1		37.500	-30.000	0
43	111	0		0		45.000	0.000	0
44	113	0		0		45.000	-3.750	0

OUTPUT FROM PS-NFAP (CONTINUED)

45	110	0	0	45.000	-7.500	0
46	109	0	0	45.000	-11.250	0
47	107	0	0	45.000	-15.000	0
48	106	0	0	45.000	-18.750	0
49	104	0	0	45.000	-22.500	0
50	102	0	0	45.000	-26.250	0
51	101	1	1	45.000	-30.000	0
52	114	0	0	52.500	0.000	0
53	112	0	0	52.500	-7.500	0
54	108	0	0	52.500	-15.000	0
55	105	0	0	52.500	-22.500	0
56	103	1	1	52.500	-30.000	0
57	127	0	0	60.000	0.000	0
58	126	0	0	60.000	-3.750	0
59	124	0	0	60.000	-7.500	0
60	123	0	0	60.000	-11.250	0
61	121	0	0	60.000	-15.000	0
62	120	0	0	60.000	-18.750	0
63	118	0	0	60.000	-22.500	0
64	116	0	0	60.000	-26.250	0
65	115	1	1	60.000	-30.000	0
66	128	0	0	67.500	0.000	0
67	125	0	0	67.500	-7.500	0
68	122	0	0	67.500	-15.000	0
69	119	0	0	67.500	-22.500	0
70	117	1	1	67.500	-30.000	0
71	152	0	0	75.000	0.000	0
72	151	0	0	75.000	-3.750	0
73	149	0	0	75.000	-7.500	0
74	148	0	0	75.000	-11.250	0
75	146	0	0	75.000	-15.000	0
76	145	0	0	75.000	-18.750	0
77	143	0	0	75.000	-22.500	0
78	130	0	0	75.000	-26.250	0
79	129	1	1	75.000	-30.000	0
80	153	0	0	82.500	0.000	0
81	150	0	0	82.500	-7.500	0
82	147	0	0	82.500	-15.000	0
83	144	0	0	82.500	-22.500	0
84	131	1	1	82.500	-30.000	0
85	171	0	0	90.000	0.000	0
86	170	0	0	90.000	-3.750	0
87	168	0	0	90.000	-7.500	0
88	167	0	0	90.000	-11.250	0
89	165	0	0	90.000	-15.000	0
90	156	0	0	90.000	-18.750	0
91	154	0	0	90.000	-22.500	0
92	133	0	0	90.000	-26.250	0
93	132	1	1	90.000	-30.000	0
94	172	0	0	97.500	0.000	0
95	169	0	0	97.500	-7.500	0
96	166	0	0	97.500	-15.000	0
97	155	0	0	97.500	-22.500	0

OUTPUT FROM PS-NFAP (CONTINUED)

98	134	1	1	97.500	-30.000	0
99	184	0	0	105.000	0.000	0
100	183	0	0	105.000	-3.750	0
101	181	0	0	105.000	-7.500	0
102	175	0	0	105.000	-11.250	0
103	173	0	0	105.000	-15.000	0
104	159	0	0	105.000	-18.750	0
105	157	0	0	105.000	-22.500	0
106	136	0	0	105.000	-26.250	0
107	135	1	1	105.000	-30.000	0
108	185	0	0	112.500	0.000	0
109	182	0	0	112.500	-7.500	0
110	174	0	0	112.500	-15.000	0
111	158	0	0	112.500	-22.500	0
112	137	1	1	112.500	-30.000	0
113	190	0	0	120.000	0.000	0
114	189	0	0	120.000	-3.750	0
115	186	0	0	120.000	-7.500	0
116	179	0	0	120.000	-11.250	0
117	176	0	0	120.000	-15.000	0
118	163	0	0	120.000	-18.750	0
119	160	0	0	120.000	-22.500	0
120	139	0	0	120.000	-26.250	0
121	138	1	1	120.000	-30.000	0
122	193	0	0	127.500	0.000	0
123	188	0	0	127.500	-7.500	0
124	178	0	0	127.500	-15.000	0
125	162	0	0	127.500	-22.500	0
126	142	1	1	127.500	-30.000	0
127	192	1	0	135.000	0.000	0
128	191	1	0	135.000	-3.750	0
129	187	1	0	135.000	-7.500	0
130	180	1	0	135.000	-11.250	0
131	177	1	0	135.000	-15.000	0
132	164	1	0	135.000	-18.750	0
133	161	1	0	135.000	-22.500	0
134	141	1	0	135.000	-26.250	0
135	140	1	1	135.000	-30.000	0
136	48	1	0	0.000	0.937	0
137	47	1	0	0.000	1.875	0
138	42	1	0	0.000	2.812	0
139	41	1	0	0.000	3.750	0
140	31	1	0	0.000	4.687	0
141	30	1	0	0.000	5.625	0
142	19	1	0	0.000	6.562	0
143	18	1	0	0.000	7.500	0
144	11	1	0	0.000	8.437	0
145	10	1	0	0.000	9.375	0
146	3	1	0	0.000	10.312	0
147	2	1	0	0.000	11.250	0
148	46	0	0	7.500	1.875	0
149	40	0	0	7.500	3.750	0
150	29	0	0	7.500	5.625	0

OUTPUT FROM PS-NFAP (CONTINUED)

151	17	0	0	7.500	7.500	0
152	9	0	0	7.500	9.375	0
153	1	0	0	7.500	11.250	0
154	73	0	0	15.000	0.937	0
155	71	0	0	15.000	1.875	0
156	65	0	0	15.000	2.812	0
157	63	0	0	15.000	3.750	0
158	34	0	0	15.000	4.687	0
159	32	0	0	15.000	5.625	0
160	22	0	0	15.000	6.562	0
161	20	0	0	15.000	7.500	0
162	15	0	0	15.000	8.437	0
163	12	0	0	15.000	9.375	0
164	5	0	0	15.000	10.312	0
165	4	0	0	15.000	11.250	0
166	72	0	0	22.500	1.875	0
167	64	0	0	22.500	3.750	0
168	33	0	0	22.500	5.625	0
169	21	0	0	22.500	7.500	0
170	14	0	0	20.625	9.375	0
171	8	0	0	18.750	11.250	0
172	94	0	0	30.000	0.937	0
173	91	0	0	30.000	1.875	0
174	69	0	0	30.000	2.812	0
175	66	0	0	30.000	3.750	0
176	36	0	0	30.000	4.687	0
177	35	0	0	30.000	5.625	0
178	24	0	0	30.000	6.562	0
179	23	0	0	30.000	7.500	0
180	16	0	0	28.125	8.437	0
181	13	0	0	26.250	9.375	0
182	7	0	0	24.375	10.312	0
183	6	0	0	22.500	11.250	0
184	93	0	0	35.625	1.875	0
185	68	0	0	33.750	3.750	0
186	38	0	0	31.875	5.625	0
187	95	0	0	43.125	0.937	0
188	92	0	0	41.250	1.875	0
189	70	0	0	39.375	2.812	0
190	67	0	0	37.500	3.750	0
191	39	0	0	35.625	4.687	0
192	37	0	0	33.750	5.625	0
193	25	0	0	31.875	6.562	0

OUTPUT FROM PS-[illegible]AP (CONTINUED)

EQUATION NUMBERS (N IS NEW NODE NUMBER)

N	Y	Z	N	Y	Z	N	Y	Z	N	Y	Z	N	Y	Z	N	Y	Z	N	Y	Z
1	1	2	2	0	3	3	0	4	4	5	6	5	7	8	6	9	10	7	11	12
8	13	14	9	15	16	10	0	17	11	0	18	12	19	20	13	21	22	14	23	24
15	25	26	16	27	28	17	29	30	18	0	31	19	0	32	20	33	34	21	35	36
22	37	38	23	39	40	24	41	42	25	43	44	26	0	0	27	0	0	28	0	45
29	46	47	30	0	48	31	0	49	32	50	51	33	52	53	34	54	55	35	56	57
36	58	59	37	60	61	38	62	63	39	64	65	40	66	67	41	0	68	42	0	69
43	70	71	44	0	72	45	0	73	46	74	75	47	0	76	48	0	77	49	78	79
50	0	80	51	0	81	52	82	83	53	0	84	54	85	86	55	0	87	56	0	88
57	0	0	58	89	90	59	0	0	60	91	92	61	93	94	62	95	96	63	97	98
64	99	100	65	101	102	66	103	104	67	105	106	68	107	108	69	109	110	70	111	112
71	113	114	72	115	116	73	117	118	74	119	120	75	121	122	76	123	124	77	125	126
78	127	128	79	129	130	80	131	132	81	133	134	82	0	0	83	135	136	84	0	0
85	137	138	86	139	140	87	141	142	88	143	144	89	145	146	90	147	148	91	149	150
92	151	152	93	153	154	94	155	156	95	157	158	96	159	160	97	161	162	98	163	164
99	165	166	100	167	168	101	0	0	102	169	170	103	0	0	104	171	172	105	173	174
106	175	176	107	177	178	108	179	180	109	181	182	110	183	184	111	185	186	112	187	188
113	189	190	114	191	192	115	0	0	116	193	194	117	0	0	118	195	196	119	197	198
120	199	200	121	201	202	122	203	204	123	205	206	124	207	208	125	209	210	126	211	212
127	213	214	128	215	216	129	0	0	130	217	218	131	0	0	132	0	0	133	219	220
134	0	0	135	0	0	136	221	222	137	0	0	138	0	0	139	223	224	140	0	0
141	0	225	142	0	0	143	226	227	144	228	229	145	230	231	146	232	233	147	234	235
148	236	237	149	238	239	150	240	241	151	242	243	152	244	245	153	246	247	154	248	249
155	250	251	156	252	253	157	254	255	158	256	257	159	258	259	160	260	261	161	0	262
162	263	264	163	265	266	164	0	267	165	268	269	166	270	271	167	272	273	168	274	275
169	276	277	170	278	279	171	280	281	172	282	283	173	284	285	174	286	287	175	288	289
176	290	291	177	0	292	178	293	294	179	295	296	180	0	297	181	298	299	182	300	301
183	302	303	184	304	305	185	306	307	186	308	309	187	0	310	188	311	312	189	313	314
190	315	316	191	0	317	192	0	318	193	319	320									

REFERENCE NODE FOR GHOST ELEMENT . (IDSET) = 0
REFERENCE DOF FOR GHOST ELEMENT . (IDSV) = 0

OUTPUT FROM PS-NFAP (CONTINUED)

L O A D   C O N T R O L   D A T A

```
NUMBER OF NODAL LOADS              =  135
NUMBER OF LOAD CURVES              =    7
MAX NO. OF POINTS IN LOAD CURVES   =    4
NO. OF UNLOADING STEP              =    0
```

OUTPUT FROM PS-NFAP (CONTINUED)

```
E L E M E N T   G R O U P   D A T A


E L E M E N T   G R O U P .......................... =   1    ( NONLINEAR )


E L E M E N T   D E F I N I T I O N

ELEMENT TYPE . . . . . . . . . . . .( NPAR(1) ). . =   2
    EQ.1, TRUSS ELEMENTS
    EQ.2, 2-DIM ELEMENTS

NUMBER OF ELEMENTS. . . . . . . . . . .( NPAR(2) ). . =  52

TYPE OF NONLINEAR ANALYSIS . . . . . .( NPAR(3) ). . =   4
    EQ.1, MATERIAL NONLINEARITY ONLY
    EQ.4, UPDATED LAGRANGIAN (LARGE ROTATION)

MAX NUMBER OF NODES DESCRIBING
    ANY ONE ELEMENT . . . . . . . . . .( NPAR(7) ). . =   8

NUMBER OF INTEGRATION POINTS FOR
    ELEMENT STIFFNESS GENERATION. . . .( NPAR(10)). . =   2

M A T E R I A L   D E F I N I T I O N

MATERIAL MODEL. . . . . . . . . . . . .( NPAR(15)). . =  10
    EQ. 1, ISOTROPIC
    EQ.10, CAP MODEL

NUMBER OF DIFFERENT SETS OF MATERIAL
    CONSTANTS . . . . . . . . . . . . .( NPAR(16)). . =  10

NUMBER OF MATERIAL CONSTANTS PER SET. .( NPAR(17)). . =  22

DIMENSION OF STORAGE ARRAY (WA)
    PER INTEGRATION POINT . . . . . . .( NPAR(18)). . =  12
```

OUTPUT FROM PS-NFAP (CONTINUED)

```
MATERIAL CONSTANTS SET NUMBER ....      1    (overconsolidated crust:
                                              z= 0.0 to -7.5)
    PROP( 1) ....... =  0.980000E+02
    PROP( 2) ....... =  0.100000E+01
    PROP( 3) ....... =  0.211600E+01
    PROP( 4) ....... =  0.100000E+01
    PROP( 5) ....... =  0.000000E+00
    PROP( 6) ....... =  0.460000E+00
    PROP( 7) ....... =  0.172000E+00
    PROP( 8) ....... =  0.100000E-03
    PROP( 9) ....... =  0.146000E+00
    PROP(10) ....... =  0.119000E+01
    PROP(11) ....... =  0.747000E+00
    PROP(12) ....... = -0.740000E+00
    PROP(13) ....... =  0.100000E+00
    PROP(14) ....... =  0.200000E+01
    PROP(15) ....... =  0.530000E-01
    PROP(16) ....... =  0.000000E+00
    PROP(17) ....... =  0.600000E+00
    PROP(18) ....... =  0.000000E+00
    PROP(19) ....... = -0.100000E+02
    PROP(20) ....... =  0.000000E+00
    PROP(21) ....... =  0.000000E+00
    PROP(22) ....... =  0.000000E+00

MATERIAL CONSTANTS SET NUMBER ....      2    (normally consolidated foundation soil:
                                              z = -7.5 to -15.0)
    PROP( 1) ....... =  0.980000E+02
    PROP( 2) ....... =  0.100000E+01
    PROP( 3) ....... =  0.211600E+01
    PROP( 4) ....... =  0.100000E+01
    PROP( 5) ....... =  0.000000E+00
    PROP( 6) ....... =  0.460000E+00
    PROP( 7) ....... =  0.183000E+00
    PROP( 8) ....... =  0.100000E-03
    PROP( 9) ....... =  0.146000E+00
    PROP(10) ....... =  0.806000E+00
    PROP(11) ....... =  0.747000E+00
    PROP(12) ....... =  0.100000E+01
    PROP(13) ....... =  0.100000E+00
    PROP(14) ....... =  0.100000E+01
    PROP(15) ....... =  0.530000E-01
    PROP(16) ....... =  0.000000E+00
    PROP(17) ....... =  0.470000E+00
    PROP(18) ....... =  0.000000E+00
    PROP(19) ....... =  0.100000E+02
    PROP(20) ....... =  0.000000E+00
    PROP(21) ....... =  0.000000E+00
    PROP(22) ....... =  0.000000E+00
```

OUTPUT FROM PS-NFAP (CONTINUED)

```
MATERIAL CONSTANTS SET NUMBER ....     3    (normally consolidated foundation soil;
                                              z = -15.0 to -22.5)

    PROP( 1) ...... =  0.980000E+02
    PROP( 2) ...... =  0.100000E+01
    PROP( 3) ...... =  0.211600E+01
    PROP( 4) ...... =  0.100000E+01
    PROP( 5) ...... =  0.000000E+00
    PROP( 6) ...... =  0.460000E+00
    PROP( 7) ...... =  0.183000E+00
    PROP( 8) ...... =  0.100000E-03
    PROP( 9) ...... =  0.146000E+00
    PROP(10) ...... =  0.484000E+00
    PROP(11) ...... =  0.747000E+00
    PROP(12) ...... =  0.100000E+01
    PROP(13) ...... =  0.100000E+00
    PROP(14) ...... =  0.100000E+01
    PROP(15) ...... =  0.530000E-01
    PROP(16) ...... =  0.000000E+00
    PROP(17) ...... =  0.470000E+00
    PROP(18) ...... =  0.000000E+00
    PROP(19) ...... =  0.100000E+02
    PROP(20) ...... =  0.000000E+00
    PROP(21) ...... =  0.000000E+00
    PROP(22) ...... =  0.000000E+00

MATERIAL CONSTANTS SET NUMBER ....     4    (normally consolidated foundation soil;
                                              z= -22.5 to -30.0)

    PROP( 1) ...... =  0.980000E+02
    PROP( 2) ...... =  0.100000E+01
    PROP( 3) ...... =  0.211600E+01
    PROP( 4) ...... =  0.100000E+01
    PROP( 5) ...... =  0.000000E+00
    PROP( 6) ...... =  0.460000E+00
    PROP( 7) ...... =  0.183000E+00
    PROP( 8) ...... =  0.100000E-03
    PROP( 9) ...... =  0.146000E+00
    PROP(10) ...... =  0.346000E+00
    PROP(11) ...... =  0.747000E+00
    PROP(12) ...... =  0.100000E+01
    PROP(13) ...... =  0.100000E+00
    PROP(14) ...... =  0.100000E+01
    PROP(15) ...... =  0.530000E-01
    PROP(16) ...... =  0.000000E+00
    PROP(17) ...... =  0.470000E+00
    PROP(18) ...... =  0.000000E+00
    PROP(19) ...... =  0.100000E+02
    PROP(20) ...... =  0.000000E+00
    PROP(21) ...... =  0.000000E+00
    PROP(22) ...... =  0.000000E+00
```

OUTPUT FROM PS-NFAP (CONTINUED)

```
MATERIAL CONSTANTS SET NUMBER ....     5    (embankment: lift no. 1)

    PROP( 1) ...... =  0.190000E+03
    PROP( 2) ...... =  0.650000E+00
    PROP( 3) ...... =  0.211600E+01
    PROP( 4) ...... =  0.200000E+02
    PROP( 5) ...... =  0.000000E+00
    PROP( 6) ...... =  0.330000E+00
    PROP( 7) ...... =  0.170000E+00
    PROP( 8) ...... =  0.100000E-03
    PROP( 9) ...... =  0.100000E+01
    PROP(10) ...... =  0.100000E+01
    PROP(11) ...... =  0.100000E+01
    PROP(12) ...... = -0.100000E+10
    PROP(13) ...... =  0.100000E-01
    PROP(14) ...... =  0.200000E+01
    PROP(15) ...... =  0.000000E+00
    PROP(16) ...... =  0.000000E+00
    PROP(17) ...... =  0.000000E+00
    PROP(18) ...... =  0.000000E+00
    PROP(19) ...... =  0.000000E+00
    PROP(20) ...... =  0.100000E-01
    PROP(21) ...... =  0.125000E+00
    PROP(22) ...... =  0.624000E-01

MATERIAL CONSTANTS SET NUMBER ....     6    (embankment: lift no. 2)

    PROP( 1) ...... =  0.190000E+03
    PROP( 2) ...... =  0.650000E+00
    PROP( 3) ...... =  0.211600E+01
    PROP( 4) ...... =  0.200000E+02
    PROP( 5) ...... =  0.000000E+00
    PROP( 6) ...... =  0.330000E+00
    PROP( 7) ...... =  0.170000E+00
    PROP( 8) ...... =  0.100000E-03
    PROP( 9) ...... =  0.100000E+01
    PROP(10) ...... =  0.100000E+01
    PROP(11) ...... =  0.100000E+01
    PROP(12) ...... = -0.100000E+10
    PROP(13) ...... =  0.100000E-01
    PROP(14) ...... =  0.200000E+01
    PROP(15) ...... =  0.000000E+00
    PROP(16) ...... =  0.000000E+00
    PROP(17) ...... =  0.000000E+00
    PROP(18) ...... =  0.000000E+00
    PROP(19) ...... =  0.000000E+00
    PROP(20) ...... =  0.100000E+01
    PROP(21) ...... =  0.125000E+00
    PROP(22) ...... =  0.624000E-01
```

OUTPUT FROM PS-NFAP (CONTINUED)

```
MATERIAL CONSTANTS SET NUMBER ....     7    (embankment; lift no. 3)

     PROP( 1) ...... =  0.190000E+03
     PROP( 2) ...... =  0.650000E+00
     PROP( 3) ...... =  0.211600E+01
     PROP( 4) ...... =  0.200000E+02
     PROP( 5) ...... =  0.000000E+00
     PROP( 6) ...... =  0.330000E+00
     PROP( 7) ...... =  0.170000E+00
     PROP( 8) ...... =  0.100000E-03
     PROP( 9) ...... =  0.100000E+01
     PROP(10) ...... =  0.100000E+01
     PROP(11) ...... =  0.100000E+01
     PROP(12) ...... = -0.100000E+10
     PROP(13) ...... =  0.100000E-01
     PROP(14) ...... =  0.200000E+01
     PROP(15) ...... =  0.000000E+00
     PROP(16) ...... =  0.000000E+00
     PROP(17) ...... =  0.000000E+00
     PROP(18) ...... =  0.000000E+00
     PROP(19) ...... =  0.000000E+00
     PROP(20) ...... =  0.200000E+01
     PROP(21) ...... =  0.125000E+00
     PROP(22) ...... =  0.624000E-01

MATERIAL CONSTANTS SET NUMBER ....     8    (embankment; lift no. 4)

     PROP( 1) ...... =  0.190000E+03
     PROP( 2) ...... =  0.650000E+00
     PROP( 3) ...... =  0.211600E+01
     PROP( 4) ...... =  0.200000E+02
     PROP( 5) ...... =  0.000000E+00
     PROP( 6) ...... =  0.330000E+00
     PROP( 7) ...... =  0.170000E+00
     PROP( 8) ...... =  0.100000E-03
     PROP( 9) ...... =  0.100000E+01
     PROP(10) ...... =  0.100000E+01
     PROP(11) ...... =  0.100000E+01
     PROP(12) ...... = -0.100000E+10
     PROP(13) ...... =  0.100000E-01
     PROP(14) ...... =  0.200000E+01
     PROP(15) ...... =  0.000000E+00
     PROP(16) ...... =  0.000000E+00
     PROP(17) ...... =  0.000000E+00
     PROP(18) ...... =  0.000000E+00
     PROP(19) ...... =  0.000000E+00
     PROP(20) ...... =  0.300000E+01
     PROP(21) ...... =  0.125000E+00
     PROP(22) ...... =  0.624000E-01
```

OUTPUT FROM PS-NFAP (CONTINUED)

```
MATERIAL CONSTANTS SET NUMBER ....     9    (embankment: lift no. 5)

    PROP( 1) ...... =  0.190000E+03
    PROP( 2) ...... =  0.650000E+00
    PROP( 3) ...... =  0.211600E+01
    PROP( 4) ...... =  0.200000E+02
    PROP( 5) ...... =  0.000000E+00
    PROP( 6) ...... =  0.330000E+00
    PROP( 7) ...... =  0.170000E+00
    PROP( 8) ...... =  0.100000E-03
    PROP( 9) ...... =  0.100000E+01
    PROP(10) ...... =  0.100000E+01
    PROP(11) ...... =  0.100000E+01
    PROP(12) ...... = -0.100000E+10
    PROP(13) ...... =  0.100000E-01
    PROP(14) ...... =  0.200000E+01
    PROP(15) ...... =  0.000000E+00
    PROP(16) ...... =  0.000000E+00
    PROP(17) ...... =  0.000000E+00
    PROP(18) ...... =  0.000000E+00
    PROP(19) ...... =  0.000000E+00
    PROP(20) ...... =  0.400000E+01
    PROP(21) ...... =  0.125000E+00
    PROP(22) ...... =  0.624000E-01

MATERIAL CONSTANTS SET NUMBER ....    10    (embankment: lift no. 6)

    PROP( 1) ...... =  0.190000E+03
    PROP( 2) ...... =  0.650000E+00
    PROP( 3) ...... =  0.211600E+01
    PROP( 4) ...... =  0.200000E+02
    PROP( 5) ...... =  0.000000E+00
    PROP( 6) ...... =  0.330000E+00
    PROP( 7) ...... =  0.170000E+00
    PROP( 8) ...... =  0.100000E-03
    PROP( 9) ...... =  0.100000E+01
    PROP(10) ...... =  0.100000E+01
    PROP(11) ...... =  0.100000E+01
    PROP(12) ...... = -0.100000E+10
    PROP(13) ...... =  0.100000E-01
    PROP(14) ...... =  0.200000E+01
    PROP(15) ...... =  0.000000E+00
    PROP(16) ...... =  0.000000E+00
    PROP(17) ...... =  0.000000E+00
    PROP(18) ...... =  0.000000E+00
    PROP(19) ...... =  0.000000E+00
    PROP(20) ...... =  0.500000E+01
    PROP(21) ...... =  0.125000E+00
    PROP(22) ...... =  0.624000E-01
```

OUTPUT FROM PS-NFAP (CONTINUED)

ELEMENT INFORMATION

M	IEL	IPS	MTYP	KG	NODE1	NODE2	NODE3	NODE4	NODE5	NODE6	NODE7	NODE8
1	8	1	1	1	15	1	3	17	10	2	11	16
2	8	1	2	1	17	3	5	19	11	4	12	18
3	8	1	3	1	19	5	7	21	12	6	13	20
4	8	1	4	1	21	7	9	23	13	8	14	22
5	8	1	1	1	29	15	17	31	24	16	25	30
6	8	1	2	1	31	17	19	33	25	18	26	32
7	8	1	3	1	33	19	21	35	26	20	27	34
8	8	1	4	1	35	21	23	37	27	22	28	36
9	8	1	1	1	43	29	31	45	38	30	39	44
10	8	1	2	1	45	31	33	47	39	32	40	46
11	8	1	3	1	47	33	35	49	40	34	41	48
12	8	1	4	1	49	35	37	51	41	36	42	50
13	8	1	1	1	57	43	45	59	52	44	53	58
14	8	1	2	1	59	45	47	61	53	46	54	60
15	8	1	3	1	61	47	49	63	54	48	55	62
16	8	1	4	1	63	49	51	65	55	50	56	64
17	8	1	1	1	71	57	59	73	66	58	67	72
18	8	1	2	1	73	59	61	75	67	60	68	74
19	8	1	3	1	75	61	63	77	68	62	69	76
20	8	1	4	1	77	63	65	79	69	64	70	78
21	8	1	1	1	85	71	73	87	80	72	81	86
22	8	1	2	1	87	73	75	89	81	74	82	88
23	8	1	3	1	89	75	77	91	82	76	83	90
24	8	1	4	1	91	77	79	93	83	78	84	92
25	8	1	1	1	99	85	87	101	94	86	95	100
26	8	1	2	1	101	87	89	103	95	88	96	102
27	8	1	3	1	103	89	91	105	96	90	97	104
28	8	1	4	1	105	91	93	107	97	92	98	106
29	8	1	1	1	113	99	101	115	108	100	109	114
30	8	1	2	1	115	101	103	117	109	102	110	116
31	8	1	3	1	117	103	105	119	110	104	111	118
32	8	1	4	1	119	105	107	121	111	106	112	120
33	8	1	1	1	127	113	115	129	122	114	123	128
34	8	1	2	1	129	115	117	131	123	116	124	130
35	8	1	3	1	131	117	119	133	124	118	125	132
36	8	1	4	1	133	119	121	135	125	120	126	134
37	8	1	5	1	155	137	1	15	148	136	10	154
38	8	1	6	1	157	139	137	155	149	138	148	156
39	8	1	7	1	159	141	139	157	150	140	149	158
40	8	1	8	1	161	143	141	159	151	142	150	160
41	8	1	9	1	163	145	143	161	152	144	151	162
42	8	1	10	1	165	147	145	163	153	146	152	164
43	8	1	5	1	173	155	15	29	166	154	24	172
44	8	1	6	1	175	157	155	173	167	156	166	174
45	8	1	7	1	177	159	157	175	168	158	167	176
46	8	1	8	1	179	161	159	177	169	160	168	178
47	8	1	9	1	181	163	161	179	170	162	169	180
48	8	1	10	1	183	165	163	181	171	164	170	182
49	8	1	5	1	188	173	29	43	184	172	38	187
50	8	1	6	1	190	175	173	188	185	174	184	189
51	8	1	7	1	192	177	175	190	186	176	185	191
52	8	1	8	1	179	179	177	192	179	178	186	193

OUTPUT FROM PS-NFAP (CONTINUED)

```
E L E M E N T   G R O U P ......................... =   2    ( NONLINEAR )


M A T E R I A L   D E F I N I T I O N   F O R   G R O U P   2

MATERIAL MODEL. . . . . . . . . . . . .( NPAR(15)). . =   2
   EQ.1,   LINEAR ELASTIC
   EQ.2,   NONLINEAR ELASTIC
           (STRESS-STRAIN LAW SPECIFIED)

NUMBER OF DIFFERENT SETS OF MATERIAL
    CONSTANTS . . . . . . . . . . . . . .( NPAR(16)). . =   1

NUMBER OF MATERIAL CONSTANTS PER SET. .( NPAR(17)). . =   6


E L E M E N T   D E F I N I T I O N

ELEMENT TYPE . . . . . . . . . . . . . .( NPAR(1) ). . =   1
    EQ.1, TRUSS ELEMENTS
    EQ.2, 2-DIM ELEMENTS

NUMBER OF ELEMENTS. . . . . . . . . . .( NPAR(2) ). . =   3

TYPE OF ANALYSIS. . . . . . . . . . . .( NPAR(3) ). . =   2
    EQ.0, LINEAR
    EQ.1, MATERIALLY NONLINEAR ONLY
    EQ.2, EULERIAN FORMULATION



MATERIAL CONSTANTS SET NO.    1

    POINT        STRAIN          STRESS

      1       -0.1000E+01     0.0000E+00
      2       -0.1000E-03     0.1000E-03
      3        0.1000E+01     0.6000E+02

                   AREA           PINIT          TIMEON

               0.1000E+01     0.0000E+00     0.0000E+00
```

OUTPUT FROM PS-NFAP (CONTINUED)

ELEMENT INFORMATION

N	I	J	K	TYPE	IPS
1	1	10	15	1	0
2	15	24	29	1	0
3	29	38	43	1	0

TOTAL SYSTEM DATA

```
NUMBER OF EQUATIONS . . . . . . . . . . . . . . .(NEQ)    =    320
NUMBER OF MATRIX ELEMENTS . . . . . . . . . . . .(NWK)    =   8007
MAXIMUM HALF BANDWIDTH . . . . . . . . . . . . . .(MA )    =     55
MEAN HALF BANDWIDTH . . . . . . . . . . . . . . .(MAM)    =     25
MAXIMUM BLOCK LENGTH . . . . . . . . . . . . .(NEQBLK)    =   7965
NUMBER OF BLOCKS . . . . . . . . . . . . . . . .(NBLK)    =      4
(IF NBLK .GE. 2 OUT OF CORE EQUATION SOLVER IS USED)
```

OUTPUT FROM PS-NFAP (CONTINUED)

L O A D   D A T A

```
LOAD FUNCTION NUMBER   =     1     (load function 1 is for nodal loads that
NUMBER OF TIME POINTS  =     2      balance the vertical component of the
                                    specified initial stress in foundation)
TIME VALUE      FUNCTION

   0.00000    -0.1000E+01
  10.00000    -0.1000E+01


LOAD FUNCTION NUMBER   =     2     (load functions 2 through 7 are optional;
NUMBER OF TIME POINTS  =     3      they serve only as a reminder of the load
                                    applied in each construction lift; load
TIME VALUE      FUNCTION            function no. 2 corresponds to the first lift,
                                    load function no. 3 corresponds to the second
   0.00000     0.0000E+00           lift, etc.)
   1.00000    -0.1000E+01
  10.00000    -0.1000E+01


LOAD FUNCTION NUMBER   =     3
NUMBER OF TIME POINTS  =     4

TIME VALUE      FUNCTION

   0.00000     0.0000E+00
   1.00000     0.0000E+00
   2.00000    -0.1000E+01
  10.00000    -0.1000E+01


LOAD FUNCTION NUMBER   =     4
NUMBER OF TIME POINTS  =     4

TIME VALUE      FUNCTION

   0.00000     0.0000E+00
   2.00000     0.0000E+00
   3.00000    -0.1000E+01
  10.00000    -0.1000E+01
```

OUTPUT FROM PS-NFAP (CONTINUED)

LOAD FUNCTION NUMBER = 5
NUMBER OF TIME POINTS = 4

TIME VALUE	FUNCTION
0.00000	0.0000E+00
3.00000	0.0000E+00
4.00000	-0.1000E+01
10.00000	-0.1000E+01

LOAD FUNCTION NUMBER = 6
NUMBER OF TIME POINTS = 4

TIME VALUE	FUNCTION
0.00000	0.0000E+00
4.00000	0.0000E+00
5.00000	-0.1000E+01
10.00000	-0.1000E+01

LOAD FUNCTION NUMBER = 7
NUMBER OF TIME POINTS = 4

TIME VALUE	FUNCTION
0.00000	0.0000E+00
5.00000	0.0000E+00
6.00000	-0.1000E+01
10.00000	-0.1000E+01

CONCENTRATED LOADS (to balance the vertical component of the specified inital stress in the foundation)

NODE	DIRECTION		LOAD CURVE	LOAD CURVE MULTIPL
1	3	(3 = z-	1	-0.4969E+00
2	3	direction)	1	0.1987E+01
3	3		1	-0.9937E+00
4	3		1	0.1987E+01
5	3		1	-0.9937E+00
6	3		1	0.1987E+01
7	3		1	-0.9938E+00
8	3		1	0.1987E+01
9	3		1	-0.4969E+00
10	3		1	0.1987E+01
11	3		1	0.3975E+01
12	3		1	0.3975E+01
13	3		1	0.3975E+01

OUTPUT FROM PS-NFAP (CONTINUED)

14	3	
15	3	0.1987E+01
16	3	-0.9937E+00
17	3	0.3975E+01
18	3	-0.1987E+01
19	3	0.3975E+01
20	3	-0.1987E+01
21	3	0.3975E+01
22	3	-0.1987E+01
23	3	0.3975E+01
24	3	-0.9937E+00
25	3	0.1987E+01
26	3	0.3975E+01
27	3	0.3975E+01
28	3	0.3975E+01
29	3	0.1987E+01
30	3	-0.9937E+00
31	3	0.3975E+01
32	3	-0.1987E+01
33	3	0.3975E+01
34	3	-0.1987E+01
35	3	0.3975E+01
36	3	-0.1987E+01
37	3	0.3975E+01
38	3	-0.9937E+00
39	3	0.1987E+01
40	3	0.3975E+01
41	3	0.3975E+01
42	3	0.3975E+01
43	3	0.1987E+01
44	3	-0.9938E+00
45	3	0.3975E+01
46	3	-0.1987E+01
47	3	0.3975E+01
48	3	-0.1987E+01
49	3	0.3975E+01
50	3	-0.1987E+01
51	3	0.3975E+01
52	3	-0.9937E+00
53	3	0.1987E+01
54	3	0.3975E+01
55	3	0.3975E+01
56	3	0.3975E+01
57	3	0.1987E+01
58	3	-0.9937E+00
59	3	0.3975E+01
60	3	-0.1987E+01
61	3	0.3975E+01
62	3	-0.1987E+01
63	3	0.3975E+01
64	3	-0.1987E+01
65	3	0.3975E+01
66	3	-0.9937E+00
		0.1987E+01

OUTPUT FROM PS-NFAP (CONTINUED)

67	3	1	0.3975E+01
68	3	1	0.3975E+01
69	3	1	0.3975E+01
70	3	1	0.1987E+01
71	3	1	-0.9938E+00
72	3	1	0.3975E+01
73	3	1	-0.1987E+01
74	3	1	0.3975E+01
75	3	1	-0.1987E+01
76	3	1	0.3975E+01
77	3	1	-0.1987E+01
78	3	1	0.3975E+01
79	3	1	-0.9937E+00
80	3	1	0.1987E+01
81	3	1	0.3975E+01
82	3	1	0.3975E+01
83	3	1	0.3975E+01
84	3	1	0.1987E+01
85	3	1	-0.9937E+00
86	3	1	0.3975E+01
87	3	1	-0.1988E+01
88	3	1	0.3975E+01
89	3	1	-0.1987E+01
90	3	1	0.3975E+01
91	3	1	-0.1987E+01
92	3	1	0.3975E+01
93	3	1	-0.9937E+00
94	3	1	0.1988E+01
95	3	1	0.3975E+01
96	3	1	0.3975E+01
97	3	1	0.3975E+01
98	3	1	0.1988E+01
99	3	1	-0.9937E+00
100	3	1	0.3975E+01
101	3	1	-0.1988E+01
102	3	1	0.3975E+01
103	3	1	-0.1987E+01
104	3	1	0.3975E+01
105	3	1	-0.1988E+01
106	3	1	0.3975E+01
107	3	1	-0.9938E+00
108	3	1	0.1987E+01
109	3	1	0.3975E+01
110	3	1	0.3975E+01
111	3	1	0.3975E+01
112	3	1	0.1987E+01
113	3	1	-0.9938E+00
114	3	1	0.3975E+01
115	3	1	-0.1987E+01
116	3	1	0.3975E+01
117	3	1	-0.1987E+01
118	3	1	0.3975E+01
119	3	1	-0.1987E+01

OUTPUT FROM PS-NFAP (CONTINUED)

120	3	1	0.3975E+01
121	3	1	-0.9937E+00
122	3	1	0.1987E+01
123	3	1	0.3975E+01
124	3	1	0.3975E+01
125	3	1	0.3975E+01
126	3	1	0.1988E+01
127	3	1	-0.4969E+00
128	3	1	0.1987E+01
129	3	1	-0.9937E+00
130	3	1	0.1987E+01
131	3	1	-0.9937E+00
132	3	1	0.1987E+01
133	3	1	-0.9937E+00
134	3	1	0.1987E+01
135	3	1	-0.4969E+00

SUMMARY OF APPLIED LOADS

NCUR	CONCENTRATED NODAL FORCES	
	Y-DIR	Z-DIR
1	0.00000E+00	0.21465E+03
2	0.00000E+00	0.00000E+00
3	0.00000E+00	0.00000E+00
4	0.00000E+00	0.00000E+00
5	0.00000E+00	0.00000E+00
6	0.00000E+00	0.00000E+00
7	0.00000E+00	0.00000E+00

OUTPUT FROM PS-NFAP (CONTINUED)

INITIAL CONDITIONS

EQUILIBRIUM ITERATION (see page E5 for definition of output quantities)

TIME STEP = 1

```
LOAD VECTOR NORM          =  0.33293E+02
INCREMENTAL LOAD NORM     =  0.22948E+01
MAX INCREMENTAL LOAD      = -0.11484E+01
SUM GENERATED GRAV LOAD   = -0.49526E+01
```

ITERATION	UNBALANCED NORM	MAX UNBALANCED --	DOF	IDNORM	DNORM	GTOT
1	0.21531E+01	-0.91185E+00	118	0.00000E+00	0.14199E+00	-0.49517E+01
2	0.16100E+01	-0.69992E+00	118	0.14227E-01	0.15242E+00	-0.49503E+01
3	0.44816E+00	-0.19143E+00	140	0.26366E-02	0.15561E+00	-0.49467E+01
4	0.17378E+00	0.71293E-01	118	0.85915E-02	0.15839E+00	-0.49461E+01
EXIT STATUS	0.17378E+00	0.71293E-01	118	0.30357E-02	0.15691E+00	-0.49461E+01

** RESTART OPTION IS ACTIVED **

TSTART FOR NEXT RUN = 0.50000E+00

EQUILIBRIUM ITERATION

TIME STEP = 2

```
LOAD VECTOR NORM          =  0.33293E+02
INCREMENTAL LOAD NORM     =  0.22853E+01
MAX INCREMENTAL LOAD      = -0.11179E+01
SUM GENERATED GRAV LOAD   = -0.99929E+01
```

ITERATION	UNBALANCED NORM	MAX UNBALANCED --	DOF	IDNORM	DNORM	GTOT
1	0.15772E+01	-0.67279E+00	168	0.00000E+00	0.31714E+00	-0.99824E+01
2	0.63105E+00	-0.30942E+00	118	0.10558E-01	0.31276E+00	-0.99869E+01
3	0.16133E+00	0.66674E-01	118	0.30889E-02	0.31603E+00	-0.99854E+01
EXIT STATUS	0.16133E+00	0.66674E-01	118	0.10362E-02	0.31581E+00	-0.99854E+01

OUTPUT FROM PS-NFAP (CONTINUED)

P R I N T   O U T   F O R   T I M E   S T E P   2   (AT TIME 0.1000E+01)

STIFFNESS REFORMED INITIALLY FOR THIS TIME STEP
3 EQUILIBRIUM ITERATIONS PERFORMED ON THIS TIME STEP TO REESTABLISH EQUILIBRIUM

D I S P L A C E M E N T S   (NODES WITH NON-ZERO DISPLACEMENT ONLY)

NODE	Y-DISPLACEMENT	Z-DISPLACEMENT
1	0.000000E+00	-0.409125E-01
2	0.000000E+00	-0.266202E-01
3	0.000000E+00	-0.195798E-01
4	0.000000E+00	-0.130750E-01
5	0.000000E+00	-0.810756E-02
6	0.000000E+00	-0.502941E-02
7	0.000000E+00	-0.276096E-02
8	0.000000E+00	-0.105691E-02
10	0.920213E-02	-0.399757E-01
11	0.669301E-02	-0.185326E-01
12	0.430585E-02	-0.925369E-02
13	0.230905E-02	-0.301570E-02
15	0.178783E-01	-0.419913E-01
16	0.159607E-01	-0.284289E-01
17	0.130935E-01	-0.219309E-01
18	0.110977E-01	-0.153809E-01
19	0.934769E-02	-0.981936E-02
20	0.725575E-02	-0.613841E-02
21	0.517500E-02	-0.319963E-02
22	0.258461E-02	-0.114630E-02
24	0.298694E-01	-0.479594E-01
25	0.221271E-01	-0.232888E-01
26	0.152626E-01	-0.109264E-01
27	0.835636E-02	-0.336115E-02
29	0.410413E-01	-0.472187E-01
30	0.349310E-01	-0.333583E-01
31	0.331241E-01	-0.269849E-01
32	0.277819E-01	-0.175381E-01
33	0.225584E-01	-0.110332E-01
34	0.174363E-01	-0.610144E-02
35	0.116188E-01	-0.299903E-02
36	0.604161E-02	-0.999962E-03
38	0.566192E-01	-0.495124E-01
39	0.475074E-01	-0.191892E-01
40	0.299992E-01	-0.695341E-02
41	0.142814E-01	-0.194207E-02
43	0.632100E-01	0.862035E-02
44	0.604863E-01	0.589675E-02
45	0.513600E-01	0.750618E-03
46	0.418631E-01	-0.563027E-03
47	0.322420E-01	-0.135092E-02
48	0.232007E-01	-0.128957E-02
49	0.153785E-01	-0.934880E-03
50	0.756541E-02	-0.467315E-03

OUTPUT FROM PS-NFAP (CONTINUED)

D I S P L A C E M E N T S (NODES WITH NON-ZERO DISPLACEMENT ONLY)

NODE	Y-DISPLACEMENT	Z-DISPLACEMENT
52	0.510180E-01	0.226600E-01
53	0.411238E-01	0.111184E-01
54	0.278598E-01	0.334513E-02
55	0.140158E-01	0.399788E-03
57	0.401705E-01	0.197907E-01
58	0.342075E-01	0.141915E-01
59	0.313652E-01	0.100697E-01
60	0.266512E-01	0.696935E-02
61	0.216798E-01	0.480622E-02
62	0.166922E-01	0.254731E-02
63	0.111850E-01	0.110294E-02
64	0.575675E-02	0.151855E-03
66	0.288920E-01	0.159470E-01
67	0.239172E-01	0.942779E-02
68	0.167862E-01	0.401508E-02
69	0.860790E-02	0.957221E-03
71	0.212444E-01	0.119156E-01
72	0.202919E-01	0.944535E-02
73	0.178644E-01	0.698904E-02
74	0.154568E-01	0.506650E-02
75	0.126447E-01	0.340656E-02
76	0.963369E-02	0.191438E-02
77	0.651997E-02	0.773672E-03
78	0.323164E-02	0.178928E-03
80	0.165098E-01	0.940687E-02
81	0.136322E-01	0.556972E-02
82	0.950844E-02	0.244049E-02
83	0.481275E-02	0.599780E-03
85	0.127515E-01	0.746698E-02
86	0.114528E-01	0.572791E-02
87	0.102758E-01	0.415057E-02
88	0.870804E-02	0.294382E-02
89	0.708983E-02	0.194380E-02
90	0.534199E-02	0.105052E-02
91	0.356360E-02	0.404184E-03
92	0.175396E-02	0.713229E-04
94	0.938532E-02	0.561457E-02
95	0.759305E-02	0.331750E-02
96	0.520735E-02	0.141949E-02
97	0.260197E-02	0.339099E-03
99	0.676019E-02	0.463845E-02
100	0.618686E-02	0.352837E-02
101	0.546137E-02	0.252222E-02
102	0.463747E-02	0.177591E-02
103	0.374317E-02	0.116720E-02
104	0.281656E-02	0.626659E-03
105	0.186780E-02	0.232431E-03
106	0.925613E-03	0.423818E-04
108	0.464364E-02	0.363795E-02

OUTPUT FROM PS-NFAP (CONTINUED)

D I S P L A C E M E N T S (NODES WITH NON-ZERO DISPLACEMENT ONLY)

NODE	Y-DISPLACEMENT	Z-DISPLACEMENT
109	0.377184E-02	0.211714E-02
110	0.258392E-02	0.892101E-03
111	0.128567E-02	0.216838E-03
113	0.292617E-02	0.319912E-02
114	0.266395E-02	0.242281E-02
115	0.236991E-02	0.171818E-02
116	0.200690E-02	0.121066E-02
117	0.162573E-02	0.795905E-03
118	0.122059E-02	0.421794E-03
119	0.811650E-03	0.151074E-03
120	0.400088E-03	0.247881E-04
122	0.140041E-02	0.276446E-02
123	0.114570E-02	0.162182E-02
124	0.785823E-03	0.682345E-03
125	0.394956E-03	0.166868E-03
127	0.000000E+00	0.282194E-02
128	0.000000E+00	0.214509E-02
129	0.000000E+00	0.152550E-02
130	0.000000E+00	0.107991E-02
131	0.000000E+00	0.716198E-03
132	0.000000E+00	0.384042E-03
133	0.000000E+00	0.140160E-03
134	0.000000E+00	0.247124E-04
136	0.000000E+00	-0.396958E-01
137	0.000000E+00	-0.364780E-01
148	0.921338E-02	-0.514548E-01
154	0.183345E-01	-0.405256E-01
155	0.187243E-01	-0.372874E-01
166	0.313571E-01	-0.600164E-01
172	0.396910E-01	-0.451574E-01
173	0.382792E-01	-0.405489E-01
184	0.539830E-01	-0.680679E-01
187	0.514501E-01	-0.997933E-02
188	0.419403E-01	-0.258634E-01

OUTPUT FROM PS-NFAP (CONTINUED)

S T R E S S   C A L C U L A T I O N S   F O R   E L E M E N T   G R O U P   1   (2/D CONTINUUM) (PLANE STRAIN)

(see page E6 for definition of output quantities)

ELEMENT NUM/IPT	STRESS STATE	STRESS-XX	STRESS-YY	STRESS-ZZ	STRESS-YZ	PORE P	MAX STRESS	MIN STRESS	ANGLE	ETA	CAP POSITION
1											
1	ELASTIC	-0.20048E+00	-0.17960E+00	-0.36318E+00	0.37165E-02	-0.10211E+00	-0.1795E+00	-0.3633E+00	1.	0.11	-0.8352E+00
2	ELASTIC	-0.62944E-01	-0.55850E-01	-0.12028E+00	0.82640E-03	-0.19600E+00	-0.5584E-01	-0.1203E+00	1.	0.11	-0.8352E+00
3	ELASTIC	-0.20001E+00	-0.18026E+00	-0.36097E+00	0.17057E-02	-0.17511E+00	-0.1802E+00	-0.3610E+00	1.	0.11	-0.8352E+00
4	ELASTIC	-0.62749E-01	-0.56094E-01	-0.11939E+00	0.12900E-03	-0.19248E+00	-0.5609E-01	-0.1194E+00	0.	0.11	-0.8352E+00
2											
1	CAP	-0.32586E+00	-0.30088E+00	-0.72604E+00	0.84341E-03	-0.21070E+00	-0.3009E+00	-0.7260E+00	0.	0.06	-0.1503E+01
2	CAP	-0.22103E+00	-0.19964E+00	-0.49329E+00	0.33847E-02	-0.21628E+00	-0.1996E+00	-0.4933E+00	1.	0.07	-0.1023E+01
3	CAP	-0.32563E+00	-0.29771E+00	-0.72611E+00	0.45468E-02	-0.21826E+00	-0.2977E+00	-0.7262E+00	1.	0.07	-0.1504E+01
4	CAP	-0.22105E+00	-0.19994E+00	-0.49346E+00	0.53167E-03	-0.21994E+00	-0.1999E+00	-0.4935E+00	0.	0.07	-0.1023E+01
3											
1	CAP	-0.51212E+00	-0.48949E+00	-0.11258E+01	0.14284E-02	-0.20301E+00	-0.4895E+00	-0.1126E+01	0.	0.04	-0.2331E+01
2	CAP	-0.40355E+00	-0.37822E+00	-0.89585E+00	-0.65961E-03	-0.21091E+00	-0.3782E+00	-0.8959E+00	0.	0.05	-0.1854E+01
3	CAP	-0.51076E+00	-0.48249E+00	-0.11272E+01	0.12270E-01	-0.21128E+00	-0.4823E+00	-0.1127E+01	1.	0.04	-0.2333E+01
4	CAP	-0.40270E+00	-0.37225E+00	-0.89578E+00	0.90116E-02	-0.20175E+00	-0.3721E+00	-0.8959E+00	1.	0.06	-0.1855E+01
4											
1	CAP	-0.70437E+00	-0.69082E+00	-0.15167E+01	0.51448E-02	-0.20208E+00	-0.6908E+00	-0.1517E+01	0.	0.01	-0.3156E+01
2	CAP	-0.59268E+00	-0.57522E+00	-0.12925E+01	0.36041E-02	-0.20419E+00	-0.5752E+00	-0.1293E+01	0.	0.02	-0.2680E+01
3	CAP	-0.70395E+00	-0.69682E+00	-0.15168E+01	0.22395E-01	-0.19487E+00	-0.6962E+00	-0.1517E+01	2.	0.01	-0.3156E+01
4	CAP	-0.59160E+00	-0.56924E+00	-0.12935E+01	0.10359E-01	-0.19527E+00	-0.5688E+00	-0.1294E+01	1.	0.03	-0.2681E+01
5											
1	ELASTIC	-0.20124E+00	-0.17674E+00	-0.36858E+00	0.55143E-02	-0.19358E+00	-0.1766E+00	-0.3687E+00	2.	0.13	-0.8352E+00
2	ELASTIC	-0.62845E-01	-0.54444E-01	-0.12136E+00	0.47127E-03	-0.19434E+00	-0.5444E-01	-0.1214E+00	0.	0.13	-0.8352E+00
3	ELASTIC	-0.19743E+00	-0.16862E+00	-0.36402E+00	0.23958E-02	-0.13649E+00	-0.1686E+00	-0.3641E+00	1.	0.15	-0.8352E+00
4	ELASTIC	-0.63255E-01	-0.55094E-01	-0.12207E+00	0.47178E-02	-0.20159E+00	-0.5476E-01	-0.1224E+00	4.	0.13	-0.8352E+00
6											
1	CAP	-0.32552E+00	-0.29205E+00	-0.72531E+00	0.98665E-02	-0.21798E+00	-0.2918E+00	-0.7255E+00	1.	0.08	-0.1506E+01
2	CORNER	-0.22241E+00	-0.19451E+00	-0.49204E+00	0.73082E-02	-0.20519E+00	-0.1943E+00	-0.4922E+00	1.	0.09	-0.1024E+01
3	CAP	-0.32679E+00	-0.28529E+00	-0.72196E+00	0.20553E-01	-0.16867E+00	-0.2843E+00	-0.7229E+00	3.	0.10	-0.1505E+01
4	CORNER	-0.22569E+00	-0.19184E+00	-0.49277E+00	0.10140E-01	-0.26071E+00	-0.1915E+00	-0.4931E+00	2.	0.11	-0.1027E+01
7											
1	CAP	-0.50911E+00	-0.47686E+00	-0.11271E+01	0.21132E-01	-0.19470E+00	-0.4762E+00	-0.1128E+01	2.	0.05	-0.2334E+01
2	CAP	-0.40203E+00	-0.36706E+00	-0.89558E+00	0.13521E-01	-0.20630E+00	-0.3667E+00	-0.8959E+00	1.	0.07	-0.1856E+01
3	CAP	-0.50751E+00	-0.47193E+00	-0.11248E+01	0.42202E-01	-0.16474E+00	-0.4692E+00	-0.1127E+01	4.	0.06	-0.2334E+01
4	CAP	-0.40189E+00	-0.35945E+00	-0.89385E+00	0.27442E-01	-0.22411E+00	-0.3580E+00	-0.8953E+00	3.	0.08	-0.1859E+01
8											
1	CAP	-0.70339E+00	-0.69469E+00	-0.15167E+01	0.37836E-01	-0.19219E+00	-0.6930E+00	-0.1518E+01	3.	0.01	-0.3157E+01
2	CAP	-0.58983E+00	-0.56468E+00	-0.12941E+01	0.30160E-01	-0.19475E+00	-0.5634E+00	-0.1295E+01	2.	0.04	-0.2682E+01
3	CAP	-0.70206E+00	-0.69392E+00	-0.15142E+01	0.61720E-01	-0.16704E+00	-0.6893E+00	-0.1519E+01	4.	0.02	-0.3156E+01
4	CAP	-0.58904E+00	-0.56319E+00	-0.12924E+01	0.48889E-01	-0.18087E+00	-0.5599E+00	-0.1296E+01	4.	0.04	-0.2682E+01
9											
1	ELASTIC	-0.20040E+00	-0.15185E+00	-0.39069E+00	0.12622E-01	-0.10128E+00	-0.1512E+00	-0.3914E+00	3.	0.20	-0.8352E+00
2	FAILURE	-0.63166E-01	-0.49018E-01	-0.12608E+00	0.21877E-02	-0.20389E+00	-0.4896E-01	-0.1261E+00	2.	0.18	-0.8352E+00
3	ELASTIC	-0.19812E+00	-0.18297E+00	-0.35196E+00	0.62133E-01	-0.14681E+00	-0.1626E+00	-0.3723E+00	18.	0.17	-0.8352E+00
4	FAILURE	-0.57197E-01	-0.51789E-01	-0.10451E+00	0.22685E-01	-0.10309E+00	-0.4337E-01	-0.1129E+00	20.	0.20	-0.8352E+00

OUTPUT FROM PS-NFAP (CONTINUED)

10												
	1	CORNER	-0.33043E+00	-0.28427E+00	-0.71874E+00	0.43889E-01	-0.21499E+00	-0.2799E+00	-0.7231E+00	6.	0.11	-0.1500E+01
	2	CORNER	-0.22989E+00	-0.18727E+00	-0.48643E+00	0.30870E-01	-0.17958E+00	-0.1841E+00	-0.4896E+00	6.	0.15	-0.1023E+01
	3	CAP	-0.32583E+00	-0.31448E+00	-0.71204E+00	0.72870E-01	-0.17128E+00	-0.3015E+00	-0.7250E+00	10.	0.06	-0.1501E+01
	4	CAP	-0.21988E+00	-0.21004E+00	-0.47580E+00	0.63140E-01	-0.10659E+00	-0.1958E+00	-0.4900E+00	13.	0.08	-0.1018E+01
11												
	1	CAP	-0.50838E+00	-0.47878E+00	-0.11213E+01	0.62526E-01	-0.16019E+00	-0.4727E+00	-0.1127E+01	6.	0.05	-0.2333E+01
	2	CAP	-0.40183E+00	-0.36061E+00	-0.88825E+00	0.50949E-01	-0.15136E+00	-0.3557E+00	-0.8931E+00	5.	0.09	-0.1856E+01
	3	CAP	-0.51450E+00	-0.50731E+00	-0.11128E+01	0.74009E-01	-0.14297E+00	-0.4984E+00	-0.1122E+01	7.	0.03	-0.2326E+01
	4	CAP	-0.40618E+00	-0.39718E+00	-0.88034E+00	0.73807E-01	-0.10289E+00	-0.3862E+00	-0.8914E+00	8.	0.04	-0.1846E+01
12												
	1	CAP	-0.70313E+00	-0.69764E+00	-0.15107E+01	0.76758E-01	-0.14816E+00	-0.6905E+00	-0.1518E+01	5.	0.02	-0.3155E+01
	2	CAP	-0.59093E+00	-0.57063E+00	-0.12877E+01	0.64070E-01	-0.14780E+00	-0.5649E+00	-0.1293E+01	5.	0.04	-0.2679E+01
	3	CAP	-0.70378E+00	-0.70269E+00	-0.15070E+01	0.86583E-01	-0.12998E+00	-0.6935E+00	-0.1516E+01	6.	0.01	-0.3153E+01
	4	CAP	-0.59432E+00	-0.58786E+00	-0.12794E+01	0.77276E-01	-0.10193E+00	-0.5793E+00	-0.1288E+01	6.	0.02	-0.2674E+01
13												
	1	ELASTIC	-0.18888E+00	-0.22290E+00	-0.28129E+00	0.37941E-01	-0.11209E-01	-0.2042E+00	-0.3000E+00	26.	-0.16	-0.8352E+00
	2	ELASTIC	-0.53366E-01	-0.63507E-01	-0.80759E-01	0.74374E-02	-0.43524E-01	-0.6074E-01	-0.8352E-01	20.	-0.32	-0.8352E+00
	3	ELASTIC	-0.19045E+00	-0.22243E+00	-0.28699E+00	0.66105E-02	-0.34044E-01	-0.2218E+00	-0.2877E+00	6.	-0.48	-0.8352E+00
	4	ELASTIC	-0.50516E-01	-0.59493E-01	-0.75294E-01	0.22258E-02	-0.16636E-02	-0.5919E-01	-0.7560E-01	8.	-0.53	-0.8352E+00
14												
	1	ELASTIC	-0.33715E+00	-0.36760E+00	-0.68749E+00	0.62775E-01	-0.43107E-01	-0.3557E+00	-0.6994E+00	11.	-0.05	-0.1484E+01
	2	CAP	-0.23037E+00	-0.26420E+00	-0.46068E+00	0.48926E-01	-0.11551E+00	-0.2527E+00	-0.4722E+00	13.	-0.10	-0.1008E+01
	3	ELASTIC	-0.33700E+00	-0.37587E+00	-0.67873E+00	0.32049E-01	-0.40942E-01	-0.3725E+00	-0.6821E+00	6.	-0.11	-0.1484E+01
	4	ELASTIC	-0.22823E+00	-0.26192E+00	-0.45229E+00	0.17288E-01	-0.27787E-01	-0.2604E+00	-0.4538E+00	5.	-0.17	-0.1005E+01
15												
	1	CAP	-0.52169E+00	-0.53537E+00	-0.10997E+01	0.71420E-01	-0.69316E-01	-0.5265E+00	-0.1109E+01	7.	-0.01	-0.2317E+01
	2	CAP	-0.41440E+00	-0.43710E+00	-0.86634E+00	0.70500E-01	-0.11495E+00	-0.4258E+00	-0.8776E+00	9.	-0.03	-0.1839E+01
	3	ELASTIC	-0.52413E+00	-0.55318E+00	-0.10867E+01	0.54850E-01	-0.45257E-01	-0.5476E+00	-0.1092E+01	6.	-0.04	-0.2314E+01
	4	ELASTIC	-0.41729E+00	-0.45370E+00	-0.85225E+00	0.43465E-01	-0.60066E-01	-0.4490E+00	-0.8569E+00	6.	-0.08	-0.1835E+01
16												
	1	CAP	-0.70486E+00	-0.70675E+00	-0.15030E+01	0.86594E-01	-0.83484E-01	-0.6975E+00	-0.1513E+01	6.	0.01	-0.3150E+01
	2	CAP	-0.59849E+00	-0.60723E+00	-0.12719E+01	0.78906E-01	-0.10681E+00	-0.5980E+00	-0.1281E+01	7.	0.00	-0.2671E+01
	3	CAP	-0.70740E+00	-0.71350E+00	-0.15012E+01	0.74173E-01	-0.47266E-01	-0.7066E+00	-0.1508E+01	5.	0.00	-0.3146E+01
	4	CAP	-0.60416E+00	-0.62624E+00	-0.12634E+01	0.62561E-01	-0.66853E-01	-0.6202E+00	-0.1269E+01	6.	-0.02	-0.2665E+01
17												
	1	ELASTIC	-0.18980E+00	-0.21097E+00	-0.29630E+00	0.47655E-02	-0.24651E-01	-0.2107E+00	-0.2966E+00	3.	-0.24	-0.8352E+00
	2	ELASTIC	-0.50642E-01	-0.58020E-01	-0.77185E-01	0.23906E-02	-0.34847E-02	-0.5773E-01	-0.7748E-01	7.	-0.36	-0.8352E+00
	3	ELASTIC	-0.18904E+00	-0.20421E+00	-0.30052E+00	0.23239E-02	-0.13569E-01	-0.2042E+00	-0.3006E+00	1.	-0.16	-0.8352E+00
	4	ELASTIC	-0.50695E-01	-0.55369E-01	-0.80011E-01	-0.12253E-03	-0.42430E-02	-0.5537E-01	-0.8001E-01	0.	-0.19	-0.8352E+00
18												
	1	ELASTIC	-0.33763E+00	-0.36798E+00	-0.68069E+00	0.22581E-01	-0.50026E-01	-0.3664E+00	-0.6903E+00	4.	-0.09	-0.1484E+01
	2	ELASTIC	-0.22771E+00	-0.25389E+00	-0.45860E+00	0.14370E-01	-0.20336E-01	-0.2529E+00	-0.4596E+00	4.	-0.12	-0.1005E+01
	3	ELASTIC	-0.33552E+00	-0.36015E+00	-0.68950E+00	0.14981E-01	-0.19459E-01	-0.3595E+00	-0.6902E+00	3.	-0.07	-0.1484E+01
	4	ELASTIC	-0.22761E+00	-0.24833E+00	-0.46383E+00	0.63838E-02	-0.10887E-01	-0.2481E+00	-0.4640E+00	2.	-0.10	-0.1005E+01
19												
	1	ELASTIC	-0.52492E+00	-0.55235E+00	-0.10902E+01	0.41018E-01	-0.56660E-01	-0.5491E+00	-0.1093E+01	4.	-0.04	-0.2314E+01
	2	ELASTIC	-0.41466E+00	-0.44562E+00	-0.85161E+00	0.28429E-01	-0.22110E-01	-0.4436E+00	-0.8536E+00	4.	-0.07	-0.1835E+01
	3	ELASTIC	-0.52283E+00	-0.54481E+00	-0.10908E+01	0.29842E-01	-0.26536E-01	-0.5432E+00	-0.1092E+01	3.	-0.04	-0.2314E+01
	4	ELASTIC	-0.41529E+00	-0.44077E+00	-0.85856E+00	0.21369E-01	-0.31232E-01	-0.4397E+00	-0.8597E+00	3.	-0.06	-0.1835E+01

OUTPUT FROM PS-NFAP (CONTINUED)

20												
	1	CAP	-0.70881E+00	-0.71600E+00	-0.15015E+01	0.60012E-01	-0.51005E-01	-0.7114E+00	-0.1506E+01	4.	0.00	-0.3144E+01
	2	ELASTIC	-0.60184E+00	-0.62294E+00	-0.12598E+01	0.47742E-01	-0.27166E-01	-0.6194E+00	-0.1263E+01	4.	-0.03	-0.2664E+01
	3	CAP	-0.71015E+00	-0.71595E+00	-0.15017E+01	0.42829E-01	-0.27446E-01	-0.7136E+00	-0.1504E+01	3.	0.00	-0.3144E+01
	4	ELASTIC	-0.60184E+00	-0.61853E+00	-0.12642E+01	0.35578E-01	-0.27183E-01	-0.6166E+00	-0.1266E+01	3.	-0.02	-0.2664E+01
21												
	1	ELASTIC	-0.18879E+00	-0.20172E+00	-0.30217E+00	0.38042E-02	-0.99360E-02	-0.2016E+00	-0.3023E+00	2.	-0.13	-0.8352E+00
	2	ELASTIC	-0.50692E-01	-0.54378E-01	-0.80993E-01	-0.19277E-03	-0.42045E-02	-0.5438E-01	-0.8099E-01	0.	-0.14	-0.8352E+00
	3	ELASTIC	-0.18877E+00	-0.19884E+00	-0.30500E+00	0.10153E-02	-0.96978E-02	-0.1988E+00	-0.3050E+00	1.	-0.09	-0.8352E+00
	4	ELASTIC	-0.50540E-01	-0.53405E-01	-0.81459E-01	0.20005E-03	-0.20027E-02	-0.5340E-01	-0.8146E-01	0.	-0.10	-0.8352E+00
22												
	1	ELASTIC	-0.33557E+00	-0.35481E+00	-0.69489E+00	0.11016E-01	-0.19663E-01	-0.3545E+00	-0.6952E+00	2.	-0.06	-0.1484E+01
	2	ELASTIC	-0.22740E+00	-0.24286E+00	-0.46859E+00	0.55929E-02	-0.15816E-01	-0.2427E+00	-0.4687E+00	1.	-0.07	-0.1005E+01
	3	ELASTIC	-0.33507E+00	-0.34955E+00	-0.69862E+00	0.83382E-02	-0.13016E-01	-0.3494E+00	-0.6988E+00	1.	-0.04	-0.1484E+01
	4	ELASTIC	-0.22700E+00	-0.23881E+00	-0.47131E+00	0.40647E-02	-0.10033E-01	-0.2387E+00	-0.4714E+00	1.	-0.05	-0.1005E+01
23												
	1	ELASTIC	-0.52231E+00	-0.54008E+00	-0.10938E+01	0.22449E-01	-0.19059E-01	-0.5392E+00	-0.1095E+01	2.	-0.03	-0.2314E+01
	2	ELASTIC	-0.41457E+00	-0.43439E+00	-0.86254E+00	0.15469E-01	-0.20780E-01	-0.4338E+00	-0.8631E+00	2.	-0.04	-0.1835E+01
	3	ELASTIC	-0.52211E+00	-0.53478E+00	-0.10984E+01	0.16243E-01	-0.16165E-01	-0.5343E+00	-0.1099E+01	2.	-0.02	-0.2314E+01
	4	ELASTIC	-0.41424E+00	-0.42882E+00	-0.86700E+00	0.12001E-01	-0.15975E-01	-0.4285E+00	-0.8673E+00	2.	-0.03	-0.1835E+01
24												
	1	CAP	-0.70902E+00	-0.71332E+00	-0.15032E+01	0.32848E-01	-0.13729E-01	-0.7120E+00	-0.1505E+01	2.	0.00	-0.3143E+01
	2	ELASTIC	-0.60167E+00	-0.61531E+00	-0.12668E+01	0.28027E-01	-0.24732E-01	-0.6141E+00	-0.1268E+01	2.	-0.02	-0.2664E+01
	3	CAP	-0.70917E+00	-0.71216E+00	-0.15040E+01	0.22918E-01	-0.13561E-01	-0.7115E+00	-0.1505E+01	2.	0.00	-0.3143E+01
	4	ELASTIC	-0.60091E+00	-0.61041E+00	-0.12692E+01	0.19518E-01	-0.13810E-01	-0.6098E+00	-0.1270E+01	2.	-0.01	-0.2664E+01
25												
	1	ELASTIC	-0.18855E+00	-0.19637E+00	-0.30673E+00	0.14051E-02	-0.65272E-02	-0.1964E+00	-0.3067E+00	1.	-0.07	-0.8352E+00
	2	ELASTIC	-0.50554E-01	-0.52949E-01	-0.81964E-01	0.19755E-03	-0.22157E-02	-0.5295E-01	-0.8197E-01	0.	-0.08	-0.8352E+00
	3	ELASTIC	-0.18849E+00	-0.19442E+00	-0.30848E+00	0.10670E-02	-0.56710E-02	-0.1944E+00	-0.3085E+00	1.	-0.05	-0.8352E+00
	4	ELASTIC	-0.50511E-01	-0.52305E-01	-0.82463E-01	0.18073E-03	-0.15861E-02	-0.5230E-01	-0.8246E-01	0.	-0.06	-0.8352E+00
26												
	1	ELASTIC	-0.33500E+00	-0.34652E+00	-0.70142E+00	0.62725E-02	-0.12027E-01	-0.3464E+00	-0.7015E+00	1.	-0.03	-0.1484E+01
	2	ELASTIC	-0.22694E+00	-0.23649E+00	-0.47342E+00	0.36970E-02	-0.91405E-02	-0.2364E+00	-0.4735E+00	1.	-0.04	-0.1005E+01
	3	ELASTIC	-0.33471E+00	-0.34338E+00	-0.70359E+00	0.47019E-02	-0.78245E-02	-0.3433E+00	-0.7037E+00	1.	-0.02	-0.1484E+01
	4	ELASTIC	-0.22675E+00	-0.23404E+00	-0.47525E+00	0.22890E-02	-0.64402E-02	-0.2340E+00	-0.4753E+00	1.	-0.03	-0.1005E+01
27												
	1	ELASTIC	-0.52185E+00	-0.53201E+00	-0.11009E+01	0.12802E-01	-0.12348E-01	-0.5317E+00	-0.1101E+01	1.	-0.02	-0.2314E+01
	2	ELASTIC	-0.41391E+00	-0.42566E+00	-0.86906E+00	0.89649E-02	-0.11208E-01	-0.4255E+00	-0.8692E+00	1.	-0.03	-0.1835E+01
	3	ELASTIC	-0.52167E+00	-0.52917E+00	-0.11026E+01	0.08299E-02	-0.98029E-02	-0.5290E+00	-0.1103E+01	1.	-0.01	-0.2314E+01
	4	ELASTIC	-0.41380E+00	-0.42257E+00	-0.87188E+00	0.65738E-02	-0.97070E-02	-0.4225E+00	-0.8719E+00	1.	-0.02	-0.1835E+01
28												
	1	CAP	-0.70903E+00	-0.71137E+00	-0.15044E+01	0.17854E-01	-0.11029E-01	-0.7110E+00	-0.1505E+01	1.	0.00	-0.3143E+01
	2	ELASTIC	-0.60078E+00	-0.60838E+00	-0.12708E+01	0.15512E-01	-0.11056E-01	-0.6080E+00	-0.1271E+01	1.	-0.01	-0.2664E+01
	3	CAP	-0.70853E+00	-0.71023E+00	-0.15050E+01	0.12278E-01	-0.77106E-02	-0.7100E+00	-0.1505E+01	1.	0.00	-0.3143E+01
	4	ELASTIC	-0.60054E+00	-0.60608E+00	-0.12723E+01	0.10377E-01	-0.83097E-02	-0.6059E+00	-0.1272E+01	1.	-0.01	-0.2664E+01
29												
	1	ELASTIC	-0.18839E+00	-0.19343E+00	-0.30913E+00	0.97517E-03	-0.41914E-02	-0.1934E+00	-0.3091E+00	0.	-0.04	-0.8352E+00
	2	ELASTIC	-0.50494E-01	-0.52032E-01	-0.82680E-01	0.16205E-04	-0.13431E-02	-0.5203E-01	-0.8268E-01	0.	-0.05	-0.8352E+00
	3	ELASTIC	-0.18836E+00	-0.19241E+00	-0.31006E+00	0.47407E-03	-0.37682E-02	-0.1924E+00	-0.3101E+00	0.	-0.03	-0.8352E+00
	4	ELASTIC	-0.50469E-01	-0.51605E-01	-0.82943E-01	0.79008E-04	-0.97704E-03	-0.5160E-01	-0.8294E-01	0.	-0.04	-0.8352E+00

OUTPUT FROM PS-NFAP (CONTINUED)

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30
   1 ELASTIC -0.33469E+00 -0.34106E+00 -0.70503E+00  0.33984E-02 -0.74448E-02 -0.3410E+00 -0.7051E+00    1. -0.02 -0.1484E+01
   2 ELASTIC -0.22670E+00 -0.23271E+00 -0.47639E+00  0.19201E-02 -0.56205E-02 -0.2327E+00 -0.4764E+00    0. -0.02 -0.1005E+01
   3 ELASTIC -0.33455E+00 -0.34032E+00 -0.70611E+00  0.22206E-02 -0.54402E-02 -0.3403E+00 -0.7061E+00    0. -0.02 -0.1484E+01
   4 ELASTIC -0.22661E+00 -0.23146E+00 -0.47735E+00  0.10341E-02 -0.43456E-02 -0.2315E+00 -0.4774E+00    0. -0.02 -0.1005E+01
31
   1 ELASTIC -0.52150E+00 -0.52768E+00 -0.11035E+01  0.67346E-02 -0.73455E-02 -0.5276E+00 -0.1104E+01    1. -0.01 -0.2314E+01
   2 ELASTIC -0.41364E+00 -0.42085E+00 -0.87298E+00  0.46460E-02 -0.73439E-02 -0.4208E+00 -0.8730E+00    1. -0.02 -0.1835E+01
   3 ELASTIC -0.52145E+00 -0.52636E+00 -0.11046E+01  0.40565E-02 -0.65262E-02 -0.5263E+00 -0.1105E+01    0. -0.01 -0.2314E+01
   4 ELASTIC -0.41357E+00 -0.41935E+00 -0.87425E+00  0.31315E-02 -0.63418E-02 -0.4193E+00 -0.8743E+00    0. -0.01 -0.1835E+01
32
   1 CAP     -0.70840E+00 -0.70985E+00 -0.15052E+01  0.92558E-02 -0.65210E-02 -0.7097E+00 -0.1505E+01    1.  0.00 -0.3143E+01
   2 ELASTIC -0.60051E+00 -0.60512E+00 -0.12732E+01  0.79911E-02 -0.79489E-02 -0.6050E+00 -0.1273E+01    1. -0.01 -0.2664E+01
   3 CAP     -0.70828E+00 -0.70942E+00 -0.15054E+01  0.56674E-02 -0.52232E-02 -0.7094E+00 -0.1505E+01    0.  0.00 -0.3143E+01
   4 ELASTIC -0.60035E+00 -0.60399E+00 -0.12738E+01  0.47464E-02 -0.57133E-02 -0.6040E+00 -0.1274E+01    0. -0.01 -0.2664E+01
33
   1 ELASTIC -0.18831E+00 -0.19190E+00 -0.31040E+00  0.37992E-03 -0.30513E-02 -0.1919E+00 -0.3104E+00    0. -0.03 -0.8352E+00
   2 ELASTIC -0.50468E-01 -0.51561E-01 -0.83063E-01 -0.49307E-06 -0.96029E-03 -0.5156E-01 -0.8306E-01    0. -0.03 -0.8352E+00
   3 ELASTIC -0.18830E+00 -0.19161E+00 -0.31065E+00  0.76534E-04 -0.28952E-02 -0.1916E+00 -0.3107E+00    0. -0.03 -0.8352E+00
   4 ELASTIC -0.50458E-01 -0.51453E-01 -0.83139E-01  0.56057E-04 -0.82186E-03 -0.5145E-01 -0.8314E-01    0. -0.03 -0.8352E+00
34
   1 ELASTIC -0.33453E+00 -0.33966E+00 -0.70669E+00  0.13042E-02 -0.51524E-02 -0.3397E+00 -0.7067E+00    0. -0.01 -0.1484E+01
   2 ELASTIC -0.22659E+00 -0.23090E+00 -0.47784E+00  0.85306E-03 -0.40627E-02 -0.2309E+00 -0.4778E+00    0. -0.02 -0.1005E+01
   3 ELASTIC -0.33448E+00 -0.33924E+00 -0.70697E+00  0.46844E-03 -0.45243E-02 -0.3392E+00 -0.7070E+00    0. -0.01 -0.1484E+01
   4 ELASTIC -0.22655E+00 -0.23055E+00 -0.47808E+00  0.14642E-03 -0.35641E-02 -0.2305E+00 -0.4781E+00    0. -0.02 -0.1005E+01
35
   1 ELASTIC -0.52137E+00 -0.52576E+00 -0.11050E+01  0.26721E-02 -0.54062E-02 -0.5257E+00 -0.1105E+01    0. -0.01 -0.2314E+01
   2 ELASTIC -0.41350E+00 -0.41866E+00 -0.87471E+00  0.18088E-02 -0.53576E-02 -0.4187E+00 -0.8747E+00    0. -0.01 -0.1835E+01
   3 ELASTIC -0.52135E+00 -0.52545E+00 -0.11052E+01  0.64224E-03 -0.50916E-02 -0.5254E+00 -0.1105E+01    0. -0.01 -0.2314E+01
   4 ELASTIC -0.41348E+00 -0.41826E+00 -0.87502E+00  0.65282E-03 -0.50039E-02 -0.4183E+00 -0.8750E+00    0. -0.01 -0.1835E+01
36
   1 CAP     -0.70825E+00 -0.70927E+00 -0.15055E+01  0.36444E-02 -0.48551E-02 -0.7092E+00 -0.1506E+01    0.  0.00 -0.3143E+01
   2 ELASTIC -0.60033E+00 -0.60359E+00 -0.12741E+01  0.32479E-02 -0.54539E-02 -0.6036E+00 -0.1274E+01    0.  0.00 -0.2664E+01
   3 CAP     -0.70815E+00 -0.70910E+00 -0.15056E+01  0.90977E-03 -0.40684E-02 -0.7091E+00 -0.1506E+01    0.  0.00 -0.3143E+01
   4 ELASTIC -0.60029E+00 -0.60335E+00 -0.12742E+01  0.71209E-03 -0.47717E-02 -0.6033E+00 -0.1274E+01    0.  0.00 -0.2664E+01
37
   1 FAILURE -0.96396E-01 -0.69428E-01 -0.10276E+00 -0.42995E-02    DRAINED    -0.6927E-01 -0.1029E+00   -2.  0.24 -0.1170E+10
   2 FAILURE -0.30947E-01 -0.20225E-01 -0.49092E-01 -0.90007E-02    DRAINED    -0.1765E-01 -0.5167E-01  -16.  0.39 -0.1170E+10
   3 FAILURE -0.90150E-01 -0.65251E-01 -0.17129E+00  0.45706E-02    DRAINED    -0.6505E-01 -0.1715E+00    2.  0.24 -0.1170E+10
   4 FAILURE -0.30510E-01 -0.20411E-01 -0.48913E-01  0.90888E-02    DRAINED    -0.1776E-01 -0.5156E-01   16.  0.30 -0.1170E+10

38 THIS ELEMENT IS NOT ACTIVE

39 THIS ELEMENT IS NOT ACTIVE

40 THIS ELEMENT IS NOT ACTIVE

41 THIS ELEMENT IS NOT ACTIVE
```

OUTPUT FROM PS-NFAP (CONTINUED)

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42 THIS ELEMENT IS NOT ACTIVE

43
   1 FAILURE -0.10443E+00 -0.70000E-01 -0.19023E+00 -0.47141E-02   DRAINED  -0.6902E-01 -0.1904E+00  -2.  0.29 -0.1170E+10
   2 FAILURE -0.34837E-01 -0.20732E-01 -0.52970E-01 -0.91096E-02   DRAINED  -0.1834E-01 -0.5537E-01 -15.  0.45 -0.1170E+10
   3 FAILURE -0.91557E-01 -0.65945E-01 -0.17323E+00  0.57610E-02   DRAINED  -0.6564E-01 -0.1735E+00   3.  0.24 -0.1170E+10
   4 FAILURE -0.22990E-01 -0.17671E-01 -0.34601E-01  0.95559E-02   DRAINED  -0.1337E-01 -0.3890E-01  24.  0.30 -0.1170E+10

44 THIS ELEMENT IS NOT ACTIVE

45 THIS ELEMENT IS NOT ACTIVE

46 THIS ELEMENT IS NOT ACTIVE

47 THIS ELEMENT IS NOT ACTIVE

48 THIS ELEMENT IS NOT ACTIVE

49
   1 FAILURE -0.11409E+00 -0.69636E-01 -0.19403E+00 -0.11227E-01   DRAINED  -0.6864E-01 -0.1958E+00  -5.  0.36 -0.1170E+10
   2 FAILURE -0.48049E-01 -0.26423E-01 -0.68198E-01 -0.12516E-01   DRAINED  -0.2296E-01 -0.7166E-01 -15.  0.52 -0.1170E+10
   3 ELASTIC -0.70040E-01 -0.66827E-01 -0.13252E+00  0.14263E-01   DRAINED  -0.6386E-01 -0.1355E+00  12.  0.09 -0.1170E+10
   4 ELASTIC -0.33327E-01 -0.55796E-01 -0.39059E-01  0.58763E-02   DRAINED  -0.3720E-01 -0.5765E-01  72. -0.19 -0.1170E+10

50 THIS ELEMENT IS NOT ACTIVE

51 THIS ELEMENT IS NOT ACTIVE

52 THIS ELEMENT IS NOT ACTIVE
```

OUTPUT FROM PS-NFAP (CONTINUED)

S T R E S S   C A L C U L A T I O N S   F O R   E L E M E N T   G R O U P   2 (TRUSSES) (MODEL 2)
(see page E7 for location of itegration points)

	IP 1		IP 2		IP 3	
ELEMENT	FORCE	STRESS	FORCE	STRESS	FORCE	STRESS
1	0.808659E-01	0.808659E-01	0.776053E-01	0.776053E-01	0.743502E-01	0.743502E-01
2	0.103851E+00	0.103851E+00	0.987458E-01	0.987458E-01	0.936692E-01	0.936692E-01
3	0.150640E+00	0.150640E+00	0.951805E-01	0.951805E-01	0.420568E-01	0.420568E-01

LOADING TIME FUNCTION TABLE

STEP	TIME	LOAD FUNCTION						
		NO. 1	NO. 2	NO. 3	NO. 4	NO. 5	NO. 6	NO. 7
1	0.5000	-1.0000	-0.5000	0.0000	0.0000	0.0000	0.0000	0.0000
2	1.0000	-1.0000	-1.0000	0.0000	0.0000	0.0000	0.0000	0.0000

SUM OF NET BODY FORCE (GTOT) = -0.99854E+01

SUM OF GROSS BODY FORCE (GGRS) = -0.99854E+01

** RESTART OPTION IS ACTIVED **

TSTART FOR NEXT RUN = 0.10000E+01

OUTPUT FROM PS-NFAP (CONTINUED)

SOLUTION TIME LOG

FOR PROBLEM

EXAMPLE EMB - 90' BASE WIDTH - 2:1 SLOPE - WEAK CRUST - 1.875' LIFTS

```
INPUT PHASE . . . . . . . . . . . . . . . . . . . .      2.22

ASSEMBLAGE OF LINEAR STIFFNESS
  AND EFFECTIVE STIFFNESS MATRICES . . . . . . . .      0.92

TRIANGULARIZATION OF EFFECTIVE STIFFNESS MATRIX         0.00

STEP-BY-STEP SOLUTION (    2 TIME STEPS)

   CALCULATION OF EFFECTIVE LOAD VECTORS .       0.01
   UPDATING EFFECTIVE STIFFNESS MATRICES
     AND LOAD VECTORS FOR NONLINEARITIES .       5.30
   SOLUTION OF EQUATIONS . . . . . . . . .       3.27
   EQUILIBRIUM ITERATIONS  . . . . . . . .       7.31
   CALCULATION AND PRINTING OF DISPLACE-
     MENTS . . . . . . . . . . . . . . . .       0.32
   CALCULATION AND PRINTING OF STRESSES  .       1.06

                      STEP-BY-STEP TOTAL        17.61


TOTAL  SOLUTION  TIME  (MINUTES)                20.76
```

COVER DESIGN BY ALDO GIORGINI